STEWART

Performance of a Ten Kilowatt Rotary Converter

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PERFORMANCE OF A 10-KILOWATT ROTARY CONVERTER.

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Myles Vincent Stewart

ENTITLED Performance of a Ten Kilowatt Synchronous Converter

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering

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HEAD OF DEPARTMENT OF Electrical Engineering

PREFACE.

The rotary converter is a very important machine in alternating current distribution to-day. My object in this thesis was to corroborate by laboratory experiments, some of the laws governing the working of this type of machine. The Westinghouse polyphase rotary was used, being taken as a general type of modern construction in this line.

The different uses to which this machine may be applied were taken up in the best manner possible, under the circumstances, and considerable care was taken in working out the results. The number of instruments required and the lack of three-phase power from the University plant rendered it necessary to limit the investigation almost entirely to single-phase working.

The work was done alone in general, excepting in those cases where the lines of investigation were taken up by the class in the regular laboratory exercises.

In the course of the investigation it was found that:

(1) The heating of this machine was abnormal for full load and over.

(2) The no-displacement curve on the excitation base was very nearly a straight line.

(3) This rotary was slightly over-compounded for about half-load.

(4) The true efficiency did not exceed 75 per cent., for single-phase working, as a direct rotary.

(5) Hunting was, apparently, not entirely done away with by the copper damping shoes, or grids, under the pole-tips.

(6) This rotary could not be started from the slip-rings on account of the low resistance of the copper grids.

June 1901. Miles Vincent Stewart.

Department of Electrical Engineering.
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Syllabus of Lectures. ROTARY(SYNCHRONOUS)CONVERTERS.

1. DEVELOPMENT OF THE SYNCHRONOUS CONVERTER.

1.- On the conversion and the transformation of electrical energy.

2.- Derivation of synchronous converter from direct-current generator. "A converter is a rotary device transforming electric energy from one form to another without passing it through the intermediary form of mechanical energy." A.I.E.E. Rep. Com. on Standardizarion.

3.- Historical development; early and late types of machines.

II. THEORY AND PRINCIPLES.

1.- General principles underlying action of machine as converter.

2.- Relation of synchronous converter, A.C. and D.C. features, to: (a) Electric generator; (b) Electric motor.

3.- Armature inductance and reactions; as motor, as generator.

III. CLASSIFICATION.

1.- General: Synchronous commutating machines, which comprise:
(a)Synchronous(rotary) converters, A.C. to D.C., or vice versa.
(b)Double-current generators, producing both A.C. and D.C.
(c)Phase converters, A.C. to A.C., same frequency, different phase.
(d)Frequency converters, A.C. of one frequency to A.C. of another frequency, with or without change of phase.

2.- Subdivision: As to excitation: (a)self-excited; (b)separately excited. As to kinds of field windings: (a)Shunt-wound; (b)compound wound.

IV. ELEMENTS OF DESIGN.

1.- Allowances, constants, coefficients, general and special.

2.- Electric and magnetic circuit of machines; winding diagrams.

3.- Mechanical and structural details and accessories.

V. CONSTRUCTION OF MACHINES.

1- Electrical details: windings; connections A.C. end, single and polyphase circuits; relations of phase; number of poles; insulation.

2.- Magnetic considerations: lamination of armature cores and poles.

3.- Mechanical and structural details and accessories.

4.- Limitations upon frequency and voltage imposed by construction.

5.- Description of machines in commercial use.

VI. INSPECTION. See schedule C.2, of the Manual.

VII. OPERATION OF MACHINES. See A.C.Schedule 220 (1,2 and A).

1.- Starting:as D.C.motor; as A.C.induction motor;independendent motor.

2.- Functional working:reversability of machine;direct,inverted.

3.- Best operating conditions;unity power factor.

4.- Faulty working and remedies:"pumping",hunting.

5.- Faulty working due to speed variation of engine driving the generator.

6.- Influence of frequency upon operation.

7.- Regulation control of output direct-current voltage:
(a)Compounding; (b)induction regulator; (c)A.C. series of reactance.

IX. PERFORMANCE AND TESTING.

1.- Principles,methods;errors,precautions,precisions of measurments.

2.- Effect of variables on performance; voltage,frequency,excitation, character and amount of load,wave form,etc.

3.- Voltage regulations and ratios,theoretical and actual,A.C.and D.C.

4.- Phase relations and characteristics,influence of excitation.

5.- Efficinecy of,and losses of machine in various kinds of service.

6.- Magnetic determinations,leakage,distribution and magnetization.

7.- Armature resistance ~~resistance~~,inductance and reactions.

8.- Output influenced by heating and number of phases,various combinations.

9.- Special studies of machine,in various relations and services.

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Experiment 2. Alternating-current generator. One and ~~one~~ three phase. For regulation and short-circuit characteristics

Experiment 3. Double-current generator. Direct current and single-phase alternating current. For internal and dynamic characteristics.

Experiment 4. Direct-current motor. Performance and efficiency.

Experiment 5. Direct rotary. Single-phase. Performance and efficiency.

Experiment 6. Inverted rotary. Performance and efficiency.

Experiment 7. Synchronous Motor. Single-phase. Performance and efficiency.

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CHAPTER I.
DEVELOPMENT OF THE ROTARY CONVERTER.

1. The Rectifier type*, which dates back as far as 1888, was the first form. It consisted merely of a revolving commutator operated synchronously by an auxiliary motor. It was not of much commercial use, because of its excessive sparking. This was due to the fact that the circuit must be periodically broken at each reversal to avoid the alternative of short-circuiting the primary mains.

2. The Inductorium type was for direct current only, and was characterized by a series of induction coils, which might or might not be stationary, arranged in a circle and had their primary and secondary coils, one or both, connected to the respective segments of a commutator. This machine was also externally rotated. This type was brought out as earln as 1875, being improved and new patents taken out in 1882, 1883 and 1887.

3. The Motor-Generator was the first real form of rotary converter; being simply an independent generator coupled to a motor, on the same shaft or otherwise mechanically connected to it. Edison patented this device in 1881. Van Depoele patented another form or device in 1889, Henry in 1894. Their patents had to do with the number of couplings and modes of excitation.

4. The Dynamotor consisted of two machines merged into one-usually a single armature, or sometimes two armatures, but always one field, and always with independent primary and secondary coils. Its use is practically confined to direct current only, with a commutator, for each coil. The first machine of this type was patented by Van Depoele in 1882. The common direct-current dynamotor has followed the same lines of improvement as other closed coil electro-dynamic machinery, the improvement being in the design, rather than principle.

5. The Rotary Converter consists of one machine, one armature, and one coil. It is, in short, a dynamo of ordinary drum or ring-wound armature type. It is provided with two sets of terminals to its armature coils, one of which is a set of slip rings for an alternating or poly-

*Rotary Transformers; George W. Colles, A.B., M.E; The Journal of the Franklin Institute, Vol. CLI, p., 207; March 1901.

phase current, and the other a simple commutating device. This treatment puts the rotary converter last, as the more improved form. It is rather doubtful whether it is better in many cases than the motor-generator. The latter has a controllable pressure regulation, as opposed to the fixed voltage-ratio of the former, which also possesses compactness, higher efficiency, and power-factor regulation. In many cases the fixed voltage ratio has caused the rotary to be taken out and a motor-generator set installed in its place. The first appearance of the rotary converter was not as a transformer, or converter, but as a double-current generator, used to generate alternating and direct current according to the needs of the owner. Such a machine has been on exhibition at the Finsbury Technical College since 1885. It was not patented in this country until 1888 when a patent was issued to Bradley. Its true value was not recognized, at least practically, until two German firms exhibited, at the Frankfort Exposition, several large three-phase rotaries in actual operation. Since that time the rotary transformer has come into general use.

6. When the transmission* circuit is very long and must be kept clear of complicated line reactions or when the frequency used is inconveniently high or low, it is best to fall back on the motor-generator. Rotary converters can be built for any frequency, but a large machine for high frequency forces an extreme multipolar construction to keep down the peripheral speed, and this means a very complicated commutator. On the other hand, a very low frequency would compel a bipolar construction when a multipolar machine would be cheaper and better. Under ordinary conditions the rotary converter is at its best at from twenty to forty cycles per second. A motor-generator set is a few per cent., less efficient than a rotary converter and somewhat more costly, but counting in the cost and loss of efficiency in the transformers needed to supply the low voltage to the latter, the difference is less than would at first be supposed.

7. In general, the use of rotary converters is for one of two purposes- to utilize water-power situated at a point distant from the railway line, or to feed a long line from a single steam-driven station. The first involves the comparative cost of water-power and steam power delivered at a given point, the second the relative cost of steam power in stations of different sizes and with different load factors. Under present conditions the rotary converter finds its most important

*The Rotary Converter in Street Railway Work; Louis Bell Ph.D.; Street Railway Journal; Vol. XIV, No. 9, Sept. 1898.

use in the utilization of water-power for railway purposes and in this field its importance is making itself felt.

8. It is generally conceded that the motor-generator* is better than the rotary converter for arc-lighting circuits. The reason is thav special arc-lighting machines, such as the Thomson-Houston, Brush, and Wood types may be operated by alternating current motors without difficulty in many cases. From the point of efficiency, the rotary converter usually has the advantage of any motor-generator set. If the motor and generator of a large and well supported motor-generator set each has an efficinecy of 95%, the total efficiency of the apparatus would not exceed 90%, and in smaller equipments the efficiency would run as low as 80 or 85%. A rotary converter may be constructed at even a higher efficiency than the generator alone, since the weight of the armature may be less, thus resulting in a lower hysteresis loss. Even including the loss of the static transformer used with the rotary, the efficinecy is usually higher than that of a motor-generator set.

*Rotary Converters and Motor-Generators; Frank C. Perkins; Western Electrician; Vol. XXVII, No. 25, p., 396, Dec. 22, 1900.

CHAPTER II.
THEORY OF THE ROTARY CONVERTER.

9. If an ordinary closed-coil armature* were connected at two diametrically opposite points to collector-rings and rotated in an alternator field of the usual multipolar type, no current of any significance could be obtained, because the positive and negative electromotive forces in each half of the armature would at all times be practically equal.

10. Moreover, a common closed-coil, direct-current armature does not produce an alternating current, in the propdr sense of the word, nor does such a current exist at any time in any individual coil; for though the electromotive force developed in each coil does follow an approximate sine function of the time, the current in the coil remains constant during one-half a revolution, and is then abruptly reversed in direction. This does not happen to all the coils at once, but to each one successively at equal intervals of time; so that, if an alternating current is to be got from such an armature, it must be a new and different current, whether superposed upon it or otherwise independent of it. The principle upon which a true sinusoidal alternating current is obtained from such an armature depends upon the mathematical theorem that the integral of a sinusoidal quantity will give us a sinusoidal quantity; hence, integrating the sinusoidal electromotive forces developed in the individual coils of the armature over any given angle of the same, we obtain a sinusoidal E.M.F. as a resultant. Hence, a sinusoidal form of the current curve requires a sinusoidal space-distribution of the magnetic flux around the armature, while in direct-current working it is only the total-flux that affects the E.M.F. at the motor terminals; this latter fact affects the ratio of the pressure in the two external circuits.

11. Having obtained a machine which will yield two species of current, we may put in one species to run it as a motor, and take out the other as from a generator. The theory of the machine is not, however, the same in both cases. As a dynamo, the two currents are merely added together or superposed in the armature, whose reactions, resistance losses, etc., are thus merely due to their joint effects. But when the machine is used as a converter, the two currents run, in general, in opposite directions, and must be subtracted; so that the resistance losses in the

*Rotary Transformers; George W. Colles, A.B., M.E. The Journal of the Franklin Institute; Vol. CLI, No. 3; April, 1901.

armature are greatly diminished, or, looking at it in another way, a large part of the current converted either does not pass through the armature at all, or only through a few of its coils.-

12. If the continuous current be on the primary, that is, if the converter is run inverted, the speed of the machine, and hence the frequency of the alternating current produced, naturally depend on the field-excitation and the pressure in the primary circuit, and both will rise and fall together with the latter, as well as with variations in the field-strength. The difference between the primary voltage and the counter E.M.F of the machine as a generator, necessary to compensate armature losses and keep the machine running, is accounted for in the secondary circuit, alternating, by just sufficient phase-lag in the current, caused by increased self-induction, to bring the ohmic E.M.F. down to the proper level.

13. In the case where the direct current is the secondary, and the primary alternating or polyphase, it is somewhat more complex, as it is also much more frequent in practice. This is due to the fact that, whatever the counter-electromotive force produced by the machine and generated in the secondary circuit, the machine must run in synchronism with the primary circuit, or not at all. If then, so running, this counter-E.M.F. is greater or less than that of the primary mains, the current will adjust itself automatically to the proper lead or lag necessary to secure equality of the two, while at the same time, the armature currents react upon the field to assist in securing such equality. If the counter-E.M.F. of the machine at synchronism is greater than that of the primary circuit, the current will lead, and the reactions will oppose the field; if less, the current will lag, and such reactions will act to increase the field-strength. So far will thisaction go, that if the load be sufficinetly light, the machine will run without field-excitation, by the mere reaction of its armature coils. Thus the machine is to a certain extent self-regulating; but if the lead or lag of the current is unduly increased, the wattless current and armature losses become very large and the effective volts so small that the machine will fall out of step and stop.

14. It is an interesting fact that rotary converters whose fields are excited from the direct current winding are self-starting on open secondary circuit. In the case of a polyphase primary, this is due to the rotary field; but in one-phase primaries, to the fact that when starting they act like a direct-current motor in the same case; the current in fields and commutator being simultaneously reversed, the torque remaining constant in one direction; and this condition is main-

tained until the armature has reached synchronism.

15. In the case of the machine in hand, the resistance of the copper pole-tips was so small that the armature took something like 500 per cent., more than the full load current, acting like a transformer witha short circuited secondary, so that it could not be kept on the armature long enough to bring the machine up to synchronism, on account of the excessive heating.

16. If *an alternating-current voltage is impressed at the collector rings of a converter, we do not get the same voltage between adjacent sets of brushes that we do between adjacent collector rings. The direct-current voltage will always be greater than the alternating-current voltage. This is because the crest of the wave of alternating E.M.F. cannot have a greater value than the maximum E.M.F. generated in the armature conductors that act in series between phase connection taps. Moreover, since the effective value of the alternating E.M.F. wave is only $\sqrt{2}$ times the maximum value, it is not possible for the effective alternating E.M.F. ever to equal the direct-current E.M.F. the direct-current E.M.F. being equal to the maximum E.M.F. which can possibly be generated in the maximum number of armature conductors which it is possible to have acting in series at any one time. The table given below shows, first, what the theoretical voltage and current ratios are in different types of converters. They are the results derived mathematically by Mr. Steinmetz, and illustrate with accuracy the conditions that obtain in practice. The constants given assume harmonic voltage and harmonic current waves, and no allowance is made in the voltage ratios for the copper losses in the windings. In practice, therefore, a variation of as much as 15% may be found from these values, although the departure is not often more than 5%.

17. Comparative Capacity Ratios of Different Types of Rotary Converters.

	D.C.	Singlephase,	Threephase,	Twophase.
Volts between adjacent collector rings........	1	0.707	0.682	0.5
Amperes per line........	1	1.414	0.944	0.707
Ratio of copper loss in rotary to copper loss of same machine operated as a direct-current machine at same output...........	1	1.37	0.555	0.37

*Synchronous Converters; W.E. Goldsborough; Western Electricina; Vol. XXVIII, p., 102, Feb. 9, 1901.

	D.C.	Single phase,	Threephase,	Twophase.
Relative capacity of rotary converter, and same machine operated as a direct-current generator at the same temperature.....	1	0.85	1.34	1.64

18. One of the most important characteristics of the rotary converter, is the ease with which it lends itself to the regulation of the power-factor of the circuit from which it is operated. If the rotary is "underexcited, it will act like an impedance coil connected in the line, and produce a lagging current. As its excitation is increased, if the load is kept constant, the current comes more nearly in phase with the impressed E.M.F., and is at the same time reduced in value. Finally, a point is reached at which the armature current is in phase with the impressed E.M.F., and the armature is then a minimum for the given load. Any further increase in the field excitation causes the converter to act as a condenser in the line. "Over-excitation, therefore, causes the armature current to increase again, as well as to attain an angular advance over the E.M.F. The machine can, therefore, be adjusted to counteract the inductive effect of induction motor and transformer loads, and when once set for a given power-factor by a given adjustment of the field-current, it will maintain this power-factor practically constant for all loads. When operated from generator mains supplying power to well-loaded transformers, a rotary converter should be adjusted to a power-factor of 100 per cent., as the power-factor of the transformers will closely approximate this value. When so adjusted, a good rotary will maintain this condition, practically, at all loads. This statement refers primarily to uncompounded machine, or to the simplest form of rotary converter connected up and operated in the simplest manner".

CHAPTER III.

CLASSIFICATION OF ROTARY CONVERTERS.

19. Rotary* converters may be either separately excited or have both series and shunt field excitation. A third type is sometimes constructed which has neither separately nor series excited field, but in which the magnetic field is induced by the armature current. This type is known as the "Induction" converter, and has the characteristic of an induction motor, of a lagging current at all loads. It runs, however, at a synchronous speed. This latter type is not used commercially to any great extent.

20. The machine in hand is of the second type, for it has both series and shunt windings, and is also provided with copper grids at the pole tips to lessen the hunting by the damping effect of the induced eddy-currents.

21. A further classification includes the "inverted rotary" in which direct-current is put in at the commutator and alternating taken out at the collector rings. This type will be discussed in full later.

*Standard Polyphase Apparatus and Systems, Oudin, pp., 111-112.

CHAPTER IV.

ELEMENTS OF THE DESIGN OF ROTARY CONVERTERS.

22. A rotary* converter is structurally in many respects similar to a continuous-current generator, the chief outward difference consisting in the addition of a number of collector rings, and in the commutator being very much larger, in comparison with the dimensions of the rest of the machine, than in an ordinary continuous-current dynamo.

23.. The most interesting point in the design of rotary converters is the overlapping of the motor and generator currents in the armature conductors, in virtue of which, not only may the conductors be of very small cross-section for a given output, from the thermal stand-point, but, the armature reactions also being largely neutralized, large numbers of conductors may be placed on the armature, which permits of a very small flux per pole, and a correspondingly small cross-section of magnetic circuit. But the commutator must be as large as for a continuous current generator of the same output, hence a well-designed rotary converter should be characterized by a relatively large commutator and small magnetic system. This is best achieved by an armature of fairly large diameter and small axial length, and this, furthermore, gives room for the many small armature conductors, and for the many poles required for obtaining reasonable speeds at economical periodicities. The mechanical limit of centrifugal force due to high speed is an important factor in the design of the armature and commutator of a rotary converter as compared with continuous current gdnerat,rs.

24. The extent to which the motor and generator currents neutralise one another, and permit of small armature conductors to carry the resultant current, varies with the number of phases. Table, I, gives the output of a rotary converter for a given I^2R loss in the armature conductors, in the terms of the output of the same armature when used as a continuous generator, the latter being taken at 1.00 Table, II, shows the effect of power-factor.

*The Design of Rotary Converters; Parshall and Hobart, Engineering (L) Sept. 29, 1899; Oct. 13, 1899.

Table I.

Output in terms of output of contin.-cur.Generator for equal I^2R loss in conductors for power-factor=1 and conversion efficiency of 100 per cent.

Type of Rotary Converter.	Number of slip-rings.	Uniform dist.of flux over pole-face spanning entire pole pitch.	67 per cent.,of entire pole pitch.
1-phase	2	.85	.88
3-phase	3	1.34	1.38
4-phase	4	1.64	1.67
6-phase	6	1.96	1.98
12-phase	12	2.24	2.26

Table II.

Output in Terms of output of direct-current Generator for equal I^2R loss in armature conductors for 100 per cent.,efficiency,and for uniform gap distribution of flux,of 67 per cent.,polar pitch.

Type	Slip rings	Power Factor.		
		1.00	0.90	0.80
1-phase	2	.88	.81	.73
3-phase	3	1.38	1.28	1.17
4-phase	4	1.67	1.60	1.44
6-phase	6	1.98	1.92	1.77

Table III.

Per cent.,that armature or I^2R loss is of that of same armature in a direct-current generator for same output,assuming 100 percent.,conversion efficiency.

Power Factor	Per cent.,loss.
1.00	58
.87	85
.50	375
0	infinity

Gain in I^2R loss only good for power factor of about unity.

The winding is connected up to the commutator segments exactly as for an ordinary direct current dynamo. The slip-rings are connected to armature at points on the commutator.

25. As a synchronous* motor, the rotary converter depends on the frequency and this is considerably greater than in a direct-current machine, hence we may fix a maximum size.

26. The maximum current allowable from one brush set is 300 amperes. This gives the number of poles, which, with the frequency gives, R.P.M. R.P.M. = (Frequency × 60) ÷ (pairs of poles). For a certain number of poles we need a minimum diameter to avoid too great axial length of machine and to allow for sufficiently large pole-pitch. But the diameter is limited with the R.P.M. by the permissible peripheral speed. In consideration of this, we may take as a maximum limit for the size of rotary converters 1500KW., for 25 cycles. For higher frequencies, considerably less, especially if 500 volts are required. Smaller E.M.F's allow larger capacity, for fewer commutator segments per pair of poles are required.

27. Frequency should be chosen as low as possible to avoid hunting and sparking. The best frequency to use is 25 to 30 cycles per second, 30 to 40 is permissible, or with smaller machines even as high as 50 cycles. These low frequencies are advantageous in transmission because of the smaller self-induction in the leads, better parallel operation of generators, etc; but transformers used in combination with the rotaries have a low efficiency and power factor.

28. For high frequencies, low voltage is required, but a minimum limit should be about 220 volts, to avoid too heavy currents and difficult commutation.

29. For use with accumulators, about 25 per cent., variation of voltage should be possible, and an arrangement for altering the applied E.M.F. on the alternating side should be attached.

30. Since 300 amperes is taken as the maximum allowable current per set of brushes, the number of poles is given by this. For example, if we take a 500KW., 40 cycle, 500volt machine, this gives 1000 amperes direct-current, 8 poles and 250 amperes per set of brushes. From this we have 600 R.P.M. Of course the assumption of 300 amperes maximum is not a fixed one, absolutely, that is, at high frequencies a smaller number of poles and greater R.P.M. is advisable, even if it passes the limits. All such rules are merely mean values.

31. As to peripheral speed of the armature, we should not go below 75 feet per second as the ventilation of the machine is bad otherwise.

*On the Calculation of Rotary Converters. Hans Sigismund Meyer; Elektrotechnische Zeitschrift, Vol. XXII. p., 295; April 4, 1901.

As an upper limit take 1250 feet per second, but preferably 95 to 110 should be used, The diameter of the armature per pole should be at least 1 5/8".

32. For the case where the current and E.M.F., are in phase, thereis no distortion of field nor armature reaction in the real sense. But a leading current brought to the converter produces weakening of the field by armature reaction. A lagging current produces a strengthening of field. Reversing this, we can produce leading or lagging currents by increasing or decreasing the field strength. We can, therefore, use the rotary converter as a compensator in systems loaded with wattless currents. To carry this out between wide limits requires many turns per pole in the armature. Other advantages of this are that it decreases hunting, since the increased impedance offers more resistance to the wattless equalizing currents, and self-starting from alternating side is made easier, as the starting E.M.F. becomes higher and starting current less. In general the ampere turns in the armature per pole at full load, and only direct current considered, should equal or be larger than the no load ampere turns per pole in the field.

33. The permissible E.M.F. per commutator segment depends on current to be commutated. From 10 to 16 volts are usual. From the assumption of 2 commutator segments per slot, we get the number of slots. For good winding the number of slots should be divisable by the product of the number of poles and the number of phases.

34. The heating should not exceed 40°C., above atmospheric temperature. This will allow from 450 to 600 amperes per square centimeter. This is much higher than in direct-current machines, for only 60 to 64 per cent., of this current is effective in heating the machine.

35. For good commutation we require minimum self-induction, for the brushes are in the neutral zone and commutation must take place without the help of the active field. For low self-induction, many slots are used, with few turns per slot, and of the open form. But half closed slots have other advantages, for poles are usually of wrought iron to avoid hunting and with open slots a considerable core loss in pole shoes is experienced which is less for closed slots. The latter are chosen when freedom from sparking is provided for by low voltage per segment and moderate peripheral speed. Parallel winding should be adopted, with as many circuits as there are poles.

36. Although it is necessary in direct-current machines to choose a high density of lines in airgap and teeth, for sparkless commutation, it is not so in rotary converters. We can, therefore, work on the lower branch of the magnetization curve, and since the lack of armature re-

action causes the rotary converter to act like a separately excited direct-current machine, there is no danger in working on this usually unstable part of the curve. On the other hand, the upper part of the curve is better, in consideration of the tendency to hunt, since at higher saturation there is a tendency to keep the E.M.F. constant and to resist small periodic variations. Hence it must be decided for each case which part of the curve to work on.

37. The leakage is somewhat larger than in direct-current machines, because of more poles and less space between them. A mean value for machines having 70 to 80 per cent., of pole pitch as polar arc, is about 20 per cent., leakage.

38. A good average on bend of the characteristic is as follows; per square centimeter, for the armature core 6000 to 9000; for teeth 16000 to 20000; for airgap 7000 to 9000; pole core 12000 to 14000; and in magnetic frame, for cast iron 5000, wrought iron 9000 lines per square centimeter; values which differ but little from those used in the direct-current machines.

39. The breadth of machine and parts is decided by the assumption of the line density. Air passages should be about 1 7/8" apart. The insulation of sheet iron amounts to about 10 per cent. The latter is usually oxidized and japanned. The poles are made a little narrower than the armature to avoid lines entering the sides of the armature.

CHAPTER V.

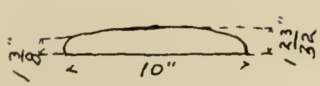
MECHANICAL AND ELECTRICAL DATA.

Mechanical Data.

r.40 Items	
Manufacturer	Westinghouse
Manufacturer's number	13575
Type of Machine	Rotary Converter
No.of Poles	4
Capacity:K.W.(Dyn.);H.P.(Mot.)	10 kw.
Speed R.P.M.	1800
Frequency,cycles per second	60
Volts,normal excitation	625 D.C. 440 A.C.
Current,normal load	16 D.C. 23 A.C.

Mechanical Data.

Shaft;material	steel
" Diam.,core portion	4.85"
" " collector portion	4.85"
" " journal bearing	1.75"
" " pulley fit	1.63"
Bearings: kind	Self oiling ring.
" length of,	5 7/8"
Pulley:Diam. over crown	10 13/32"
" face width	6 9/16"
" keyway;width x depth	1/2" × 1/4"
Belt: material	Leather
" thickness,single	Single
" in inches	1/4"
" lineal speed,ft.per min.	4900
Toothed Armatuce	
Diam.over teeth	9 1/2"
" at bottom of slots	7 1/8"
Length,over all	10 3/4"
" of core,effective	4.81"
No.of teeth	43

Windings	
Conductors per slot	48
Size of Arm.Conductors	No.16
Conductors in Multiple	2
Turns per coil in shunt field	3490
Size of Shunt field conductors	No.22
Turns per coil in series field	22
Size of series field conductors	No.11
Commutator.	
Diam.external	6.2
Length over all	2.9"
" active	2.15"
Insulation,thickness btw.seg	.018"
Segments,No.,of	129
Collector Rings	
Number of,	6
Diam.external	6"
Width of,	15/16"
Distance,centre to centre	1 1/8"
Brushes	
Type of brush,tangent,radial	Radial
Material of brushes	Carbon
Number of sets of brushes	1
No.of brushes one set	2
Length of each brush	1 7/16"
Width,of each brush	1 3/4"
Thickness of each brush	3/8"
Area of contact,one brush	.65 sq.ins.
" " " set brushes	1.3 sq.ins.
Pitch mean dis btw..pole cent.	6 15/16"
Pole arc:angle subtended	54°
Diam.of polar bore	9.71"
Depth of air gap,single	.195
Mean length Mag.Circ.of Pole	4.4"
Magnet Core	
Net area magnet core	39 sq.ins.
Yoke	
Sketch cross-section,and dimension	

RESISTANCES.

Resistance of shunt field (hot)	635 ohms
Resistance of series field (hot)	0.278 ohms
Resistance of Armature (hot)	
Including brushes	0.86 ohms
Under brushes	0.679 ohms

CHAPTER VI.
DESCRIPTION OF ROTARY CONVERTERS.

42. Rotary converters are made in standard generator sizes for frequencies of 25,30 and 60 cycles.

43. The standard voltages are 250 and 550 volts. Only two and three phase rotaries are used to any great extent, although the six-phase connection described elsewhere, is now coming into use. The single-phase is not as efficient and is not extensively used, because nearly all high tension transmission is either two or three-phase.

44. The machine which was tested in this thesis was not a standard size, but it was, nevertheless, a fair example of the modern rotary converter. The following cuts and photographs show the machine in hand and also some modern types in operation today.

45. There are numerous starting and synchronizing devices for rotary converters, but the one generally adopted to-day is to have a small induction motor mounted on the rotary shaft which quickly brings the machine up to synchronous speed. There has been recently patented an ingenious device for synchronizing from the direct-current end*. It consists of an electro-magnet mechanism which breaks the direct-current circuit at the same time that the synchronizing switch is closed, thus preventing any conflicting between the two sources.

46. Starting from the collector-rings is not advisable because it takes a heavy current at a very low power-factor and is very detrimental to the regulation of the system. Nevertheless, this method is being used some to-day, it being a very quick method.

47. Inverted rotaries are, now, practically all excited from separate exciters driven from the rotary shaft.

48. A rotary converter is inverted when converting direct to alternating current instead of vice versa. This requires no change in its design, it being merely another use to which the ordinary rotary may be put.

49. The inverted° rotary is used mainly in low-tension direct-current supply systems for supplying suburban districts with alternating current. It may be used as a connecting link between a station with low-

*A New Synchronizing Device for Rotaries; F.W.Springer; Electrical World and Engineer; Vol.35, p., 944; June 23, 1900.

°The Rotary Converter; E.W.Rice, Jr., The Sibley Journal of Engineering, Vol.XIII, p., 337, June, 1899.

tension direct-current generators, and a distant station containing alternating-current generators. It may be a connecting link between alternating and direct-current generators in the same station. In this case the distribution of load on the generating station may be changed to suit the demand.

50. When a converter is used direct, the speed of the machine must be synchronous, independent of its field excitation; any variation in the field-excitation simply changing the phase-relation of the alternating current to the impressed E.M.F.

51. When used inverted, however, with direct current as the only source of energy, the speed law of the converter follows that of a direct-current constant-potential motor, other conditions remaining constant. Its speed depends upon the field strength, its speed increasing with a decrease of field strength, and decreasing with an increase of field strength. Under such circumstances, if the alternating current supplied by the inverted converter is not in phase with its E.M.F., that is, if the power-factor is not unity, but is lagging, which is a usual commercial condition, variations of the alternating-current load will produce variations in the field strength of the inverted converter, through the effect of armature reaction. Lagging currents demagnetize the field, which results in increased speed, and a corresponding increase in the frequency which in turn adds to the lagging of the current and consequent demagnetizing power and even under some conditions the increase in speed may become dangerous. It is, therefore, necessary to provide inverted converters with safety devices which can cut them out of circuit in case the speed exceeds the danger limit.

52. The only means of regulating the speed of inverted rotaries is by changing the excitation of the field, increasing it as the lagging power-factor goes down, and decreasing it when the leading power-factor goes down. This may be done by means of the field rheostat, but requires someone to attend to it all the time, which would be inconvenient as well as expensive, especially for a small machine, so that an automatic regulator is required. The speed may be kept approximately constant by making the converter drive its own exciter*, either belted, or placed on the end of the shaft. It will be seen that with such an arrangement as the speed of the converter rises, its excitation is increased more rapidly than the speed, not only as already explained, but also by opposing the accumulative demagnetizing effect of the lagging current in the

*Some Experiments with Rotary Converters; A.G.Grier, B.Sc., and J.C.Hyde, B.Sc. Canadian Electrical News and Engineering Journal, Vol, X, p., 179, Sept, 1900/

armature. The exciter should be worked low on its magnetization curve so that a small variation of speed is accompanied by a large variation of voltage. With an exciter designed properly, the speed may be kept very nearly constant.

53. An inverted rotary running in parallel with an alternator driven by another prime mover does not have its speed changed by a change in its field-excitation, or by a change in the phase relation of the alternating current supplied by it, but behaves in a manner entirely similar to the direct converter, the alternator in the parallel circuit holding it in step after being once synchronized.

54. For large capacity* units separate transformers are always used for each phase of transmission; but for three and six-phase rotaries, up to 100 kilowatts capacity, it is always preferable to use three-phase transformers, on account of the common magnetic circuit, by means of which the pressure variation is reduced, and they act as a sort of balancer to the system. The best arrangement of transformers for three-phase working is to use three transformers, mesh-connected for both high and low-pressure sides. For if an accident happens to one transformer, such as a blown fuse, the supply is not interrupted, because the remaining two will supply three-phase current to all three phases of the rotary. The rotary reactions tend to keep the phases equally balanced. The rotaries can be kept fully loaded for a short time, two transformers doing the work of three. Star-connected transformers, under the same conditions, would supply only one-phase and the machine would have to be stopped on account of sparking at the commutator. The machine would not carry anything like full l, ad, and the system would be unbalanced. Mesh-connected transformers require 58 per cent., of copper area in the secondary as compared to that in the star-connected transformer. Star-connected transformers have 58 per cent., of line pressure across each primary winding. This gives a less winding space on account of the smaller amount of insulation. The safety from break down of the mesh system makes it by far the better.

55. The same arguments apply to the six-phase system, where the secondaries are arranged with either double "mesh" or "star" preferably "mesh". This system has two distinct mesh connections, one superposed on the other, being electrically connected through the armature of the rotary. It has three single-phase transformers, with two secondary

*E.C.Eforall; London Electrician; Vol, XLVI, Some Notes on Polyphase Substation Machinery; p., 856, March 29, 1901.

15,page 66
windings. d,c,and f (Fig.) are connected in the opposite direction to a,b,and c. The six-phase system is more complicated,but it pays. Steinmetz and Kapp have demonstrated,that,for the same mean heating of the armature coils,the output of any rotary may be increased 40 to 50 per cent.,by its use. It insures more uniform heating,the maixmum temperature being rarely more than 20 per cent.,higher than the minimum. Twelve-phase connections would increase the output in the same ratio, but would be too complicated.

56. Rotaries feeding direct-current three-wire systems cannot be paralleled from common bus-bars on the alternating-current side,because of the necessary short circuit through the armatures,so that multiple connection of the transformers is necessary. Each secondary has two windings. (Fig. 16,page 66

57. Pressure gulation consists of regulating the direct-current voltage by regulating the alternating-current volts at the collector-rings. (1)Direct variation of pressure by changing the transformer ratio,and by induction regulators which should always be placed in the secondary circuit on account of insulation difficulties. (2)By compounding the rotaries and introducing induction coils between the secondaries of the transformers and the collector-rings. The power-factor varies as the excitation according to the well-known V current curve for each load. The rotary excitation is arranged so that at no load,the input current is lagging,being about 30 to40 per cent.,of the full-load current,partly due to the under-excitation and partly due to the reactance in the line. As the load comes on,the field increases,due to the series coils,the lagging current diminishes,the impressed E.M.F.rises producing a corresponding rise in the direct-current voltage. At full load, the field flux is a maximum,the current is leading,due to over-excitation by series coils,and the direct-current voltage is raised to its proper value. By suitable proportioning the reactance and series windings excellent pressure regulation can be attained in this way in a perfectly automatic manner. The actual direct-current pressure regulation being nearly as good as in an ordinary over-compounded direct-current generator.

58. The only objection to this method is that it affects the regulation at the high-pressure feeding points,due to the variation of the power-factor.

59. Induction regulators are better for lighting work,while compounding regulation is best for street-railway work,where the load varies suddenly and through a wide range. A combination of the two is some-

times used sith good results.

60. The phenomenon known as "hunting" which is prevalent in all rotary-working is caused by the irregular rotation of the engine fly-wheel,and the rotary not being able to follow each variation in speed,commences to surge from one side of synchronism to the other,now above,now below. The copper pole-tips on the machine in hand,dampen this effect by the eddy-currents induced in them,but the only true remedy is a prime mover whose angular velocity is perfectly uniform. The steam and water turbines have solved the problem.

CHAPTER VII.
PERFORMANCE.

61. This machine may be used as a direct-current generator. In this test four sets of readings were taken:-

(1) With separate excitation and with series windings in.

(2) With separate excitation and with series windings in.

(3) Simple shunt

(4) Compound-wound.

For separate excitation the plant 500 volt source was used. A water rheostat qas used for a load.

The curves plotted from these observations are shown on Plate I, page, 47.

It will be readily seen that the inherent regulation of this machine as a direct-current generator is not very good. The armature reaction is evidently excessive, and apparently the only way to keep the voltage up is to separately excite the machine and use the series windings, with results shown in Curve I. The machine is slightly over-compounded for about half-load, but does not hold up well. The heating is excessive on account of the small magnetic area and small cross-section of armature conductors. It is not designed to be used in this way, but still will render fair service if required.

62. As an alternating-current generator this machine gives only partial satisfaction. Three sets of observations were taken:-

(1) Single-phase with a non-inductive load.

(2) Three-phase with a non-inductive load.

(3) Three-phase with an inductive load.

The machine was excited by the plant 500 volts. The single-phase non-inductive load was a water rheostat, while the three-phase load was one of the General Electric rotary converters. The power-factor was approximately adjusted by means of the excitation of the latter machine. The power of the three-phase circuit was measured by the two wattmeter mwltrod. The curves plotted from these readings are shown in Plate II, page 48. There being no compensating turns on the field, the inherent regulation is not good. The speed was about normal, be cause the generator pulley was slightly too small.

63. Plate III, page 49, shows the internal characteristics as a direct-current generator and as a single phase alternator. The field was

excited by the plant 500 volts and the Weston plant 125 volt machine in series. This was done to get a high excitation for the bend in the curve. For the low values of the excitation, the Weston was reserved, thus cutting down the 500 volts. The voltage ratio curve shows a slight decrease for high values of excitation, but in no case coming down as low as the theoretical 0.707.

64. Plate IV, page 50, shows the dynamic characteristic as a double-current generator. Here the voltage ratio curve shows more of a curved form than in the open-circuit curves, and does not come down to quite as low a value.

The loads for both direct and alternating-current sides were water rheostats.

65. Plate V, page 51, shows the short-circuit characteristic as a single-phase alternator. The armature was short-circuited through as ammeter, the field being much under-excited by the Weston 125 volt machine. The inductance of the armature kept the current down as shown in the curve, which is a straight line.

66. Plate VI, page 52, shows the working characteristics as a direct-current motor. The machine was separately excited from the plant 500 volts, and the series coils were not in service. The plant 500 volts was put in series with the Weston to supply the 625 volts necessary to run the motor. The power was absorbed by a rope-brake arranged as shown on page, 63, Fig. 6. The curves show fair performance. The slight depression in the efficiency curve was due, probably, to the fact that the voltage fell off somewhat at that point.

67. Plates VII and VIII, pages 53 and 54, show the working characteristics as a single-phase rotary-converter. The connections for this test are shown on page 64, Fig. 9 and 10. The voltage ratio does not come anywhere near the theoretical value, and the efficiency is rather poor.

68. Plates IX, X and XI, pages 54, 55, and 56, show the characteristics used as an inverted rotary. In this test, 625 volts was supplied to the direct-current brushes and one of the General Electric rotaries was run through a Westinghouse O.D. transformer from the single-phase collector-rings. The direct-current end of the General Electric rotary carried a load of lamps. The connections are shown on page 65, Fig. 14.

The input direct-current voltage was kept constant, and four sets of readings taken:-

(1) The true-watts output was kept constant and the excitation constant; speed, volts and amperes were read from which to calculate the power-factor.

(2) The speed and true-watts output were kept constant by varying

the excitation, varying the power-factor by changing the excitation of the secondary rotary.

(3) An efficiency test, with constant speed and variable excitation.

(4) An efficiency test, with constant excitation and variable speed. On the last test (4) just as my readings were finished, having a heavy lagging current in the machine, it began to hunt or race, the speed surging back and forth. Every connected instrument pulsated with the speed. If finally blew a fuse in the input circuit. The speed varied from 1700 to 2300 R.P.M. about once in two seconds. This shows the necessity of some regulating device or cut out for an inverted rotary.

69. Plates XII and XIII, pages 58 & 59, show the characteristics as a single-phase synchronous motor. The no-displacement curve of the characteristic form and efficiency is fair.

Diagram of connections on pages 63 & 64, Figs. 6 & 9.

70. Plate XIV, page 60, shows the no-load characteristics as a single-phase rotary converter. Curves I and II show the effect of the compounding. The series coils were separately excited by the Weston, and the shunt excitation kept constant. In order to make the rotary self-excitating, it was brought up to speed and synchronized with separate excitation, then the field was broken and connected acorss the direct-current brushes, the proper polarity having been ascertained with a direct-current voltmeter. The rotary ran with no field excitation without falling out of step, but it took 48 amperes and pulled the input voltage down about 30 volts. The connections for curves I and II are shown on page 64, Figs. 11 and 12.

71. Plate XV, page 61, shows the no-load characteristics as a single-phase rotary, witha series reactance in the line as a means of boosting the direct-current voltage by raising the excitation*. The secondary of one of the Westinghouse O.D. transformers was placed in series with the rotary. The curves show some interesting results. Connections-Fig. 13, page 64.

*Some Experiments with Rotary Converters. AG. Grier, B.Sc., and J.C. Hyde, B.Sc. Canadian Electrical News Vol.X, p., 175, Sept. 1900-

Table I.

Direct-current generator - Plate I.

Instruments Used.

Field Amperes - ~~W~~eston, Milli-voltmete, No. 9082, Amp. Shunt.

External Amperes - Whitney, D.C. Ammeter, No. 1940.

Terminal E.M.F. - Weston, Vm. No. 831, Multiplier - 10.

R.P.M. - Tachometer.

Compound. Curve II

No.	Field Amperes	External Amperes	Original Terminal E.M.F.	Corrected Terminal E.M.F.	R.P.M.
1	0.63	0.	637.	625.	1800.
2	0.643	2.	655.	643.	"
3	0.64	3.	651.	639.	"
4	0.64	5.	652.	640.	"
5	0.653	7.5	670.	658.	"
6	0.648	10.	664.	652.	"
7	0.649	12.5	668.	656.	"
8	0.619	15.	640.	628.	"
9	0.61	18.	615.	603.	"
10	0.62	0.	637.	625.	"
		Simple	Shunt.	Curve IV.	
1	0.63	0.	637.	625.	1800
2	0.62	3.	627.	615.	"
3	0.60	4.	608.	596.	"
4	0.593	5.	602.	590.	"
5	0.578	7.5	586.	574.	"
6	0.56	10.	566.	554.	"
7	0.55	12.5	558.	546.	"
8	0.50	16.	480.	468.	"
				Curve I.	
		Separately	Excited.	Series Coils	in.
1	0.63	0.	635.	623.	1800
2	0.622	4.	640.	628.	"
3	0.63	7.	660.	648.	"
4	0.635	10.	664.	652.	"
5	0.63	17.	660.	648.	"
	Separately	Excited, ~~Series~~	~~Coils in.~~		Curve III.
1	0.63	0.	637.	625.	1800
2	0.625	4.	635.	623.	"
3	0.62	7.	627.	615.	"
4	0.605	12.	595.	583.	"
5	0.62	15.	600.	588.	"

Table II.

Three-phase alternator. Power-factor = .80

Plate II. Curve III

The voltmeters used were Weston instruments

" Excitation — Weston Milammeter.

" Ammeters — Thomson —.

		← Leg AB		→	← Leg BC		→	← AC →					
No.	#2724 Exc.	#898 Cor. Vm.	#14010 Am.	#1060 Wm. ×4	#2322 Cor. Vm.	#14008 Am.	#213 Wm. ×4	#831 Cor. Vm.	#848 Vm.	#2322 Vm.	#831 Vm.	Mean Cor. Volts	R.P.M.
1	6.58	427.5	4.0	340.	424.	4.0	160.	422.	427.5	424	420.	424.	1925.
2	"	422.0	5.5	510.	416.5	5.6	240.	416.	422.	416.5	415.	418.	"
3	"	410.5	7.35	670.	406.8	7.5	320.	403.	410.5	406.8	401.	406.	"
4	"	390.	10.3	875.	384.8	10.5	400.	386.	390.	384.	384.	388.	1950.
5	"	380.	11.7	1020.	376.4	12.5	480.	376.5	381.	376.	375.	378.	"
6	"	365.	#13457 13.75	1180.	368.	14.0	565.	362.5	366.5	368	361.	365.	"
7	"	328.	17.6	1360.	326.4	#14030 18.5	645.	361.5	329.5	326.4	360.	327.	"
8	"	440.	0.	0.	443.	0.	0.	438.	440.	442.5	435.5	440.	1925.

No.	AB Wm.	BC Wm.	Total True watts	AB App. Watts	BC App. Watts	Total App. Watts	Resultant P. F.
1	1360.	640.	2000.	1482.	1470.	2952.	67.7
2	2040.	960.	3000.	2015.	2020.	4033.	74.3
3	2680.	1280.	3960.	2615.	2640.	5255.	75.3
4	3500.	1600.	5100.	3475.	3500.	6975.	73.2
5	4080.	1920.	6000.	3800.	4070.	7920.	75.6
6	4720.	2260.	6980.	4350.	4470.	8820.	79.2
7	5440.	2580.	8020.	4980.	5220.	10200.	78.7
8	0.	0.	0.	0.	0.	0.	0

Table III.

Three-phase alternator. Power-factor = 1.00.

Plate II. Curve II.

The instruments were the same as those used in Tab. II.

		← Leg AB			→ ← Leg BC			→ ‹ AC ›				
No.	#2724 Exc.	#898 Cor. Vm.	#14010 Am.	#1060 ×4 Wm.	#2322 Cor. Vm.	#14008 Am.	#213 ×4 Wm.	#831 Cor. Vm.	#898 Vm.	#831 Vm.	Mean Cor. Volts.	R.P.M.
1	.658	440.	0	0.	443.	0.	0.	437.	440.	435.5	440.	1925.
2	"	436.	3.05	253.	435.	3.0	250.	432.	436.	430.	437.	1975.
3	"	431.5	4.2	375.	430.	4.5	375.	427.	431.5	425.	429.	"
4	"	429.	5.42	500.	427.	5.7	500.	422.	429.	420.	426.	"
5	"	421.	6.77	625.	420.	7.0	625.	419.	421.	418.	420.	"
6	"	419.5	8.25	750.	416.5	8.5	750.	412.	419.5	411.5	416.	"
7	"	410.5	9.35	875.	409.6	10.5	875.	406.	410.5	405.	409.	"
8	"	405.	11.15	1000.	404.	12.0	1000.	403.	405.	400.	404.	1900.
9	"	397.	13.	1125.	395.	13.0	1125.	392.	397.	391.	395.	1875.
10	"	387.	#13457 15.0	1247.5	386.	15.0	1250.	384.	387.	382.	386.	"

No.	AB Wm.	BC Wm.	Total True-watts	AB App. Watts.	BC App. watts	Total App. Watts	Resultant P. F.
1	1012.						
2	1500.	1000.	2012.	1152.	1130.	2282.	88.2
3	2000.	1500.	3000.	1566.	1676.	3242.	92.5
4	2500.	2000.	4000.	2015.	2100.	4115.	97.3
5	3000.	2500.	5000.	2470.	2541.	5011.	99.7
6	3500.	3000.	6000.	2990.	3070.	6060.	99.5
7	4000.	3500.	7000.	3320.	3720.	7040.	99.
8	4500.	4000.	8000.	3900.	4200.	8100.	98.8
9	4980.	4500.	9000.	4470.	4460.	8930.	100.
10		5000.	9980.	5030.	5010.	10 040.	99

Table IV.

Alternator - Single-phase - Non-inductive Load.

Plate II — Curve I.

Weston A.C. Voltmeter - Multiplier 4.

Thomson A.C. Ammeter -

Weston Wattmeter - Multiplier 4.

Weston D.C. Milli-voltmeter - Amp. Shunt - Field I

Tachometer —

No.	#2322 Vm. ×4	#13457 Am.	#1505 Wm. ×4	#9082 Exc.	R.P.M.	#2322 ×4	Kw.	#2322 Cor.
1	121.2	0.	0.	.6	1900	484.8	0.	482.
2	119.6	2.	.38	"	"	478.4	1.52	476.
3	117.8	5.	.6	"	"	471.2	2.4	468.5
4	116.	7.5	.88	"	1850	464.	3.52	461.5
5	114.5	10.	1.14	"	1875	458.	4.56	455.8
6	109.5	15.	1.64	"	1875	438.	6.56	435.
7	107.2	18.	1.9	"	1800	428.8	7.6	426.
8	102.2	20.	2.08	"	1800	408.8	8.32	405.6
9	100.5	23.	2.38	"	"	402.	9.52	399.
10	98.5	25.	2.46	"	"	394.0	9.84	391.

Table V.

Single-phase - Short-circuit Characteristic.

Plate V - Curve I -

Thomson A.C. Ammeter - Weston Millivoltmeter - Amp. Shunt.

No.	#9082 Excitation	#14030 Arm. Current	No	Excitation	Arm. Current.
1	.06	4.	8	.20	16.
2	.08	6.	9	.22	17.7
3	.10	7.6	10	.24	19.4
4	.12	9.2	11	.26	21.1
5	.14	11.2	12	.28	22.7
6	.16	12.7	13	.298	24.
7	.18	14.6			

Table VI

Plate III.

Alternating and Direct-current Internal Characteristics.

No.	Weston milli Vm. Amp. Shunt. #9082 Excit.	Weston A.C. Vm. #831 ×10 D.C. Volts	Weston A.C. Vm. #2322 ×4 A.C. Volts	Tachometer R.P.M.	#831 Cor. D.C. Volts	#2322. Cor. A.C. Volts.	D.C. Volts @ 1800 R.P.M.	A.C. Volts @ 1800 R.P.M.	Voltage Ratio A.C. ÷ D.C.
1.	0.	11.5 O.K.	7. O.K.	1925	11.5	7.	10.7	6.5	.61
2.	.25	28.5	56.3	"	280.	225.2	262.	210.	.80
3.	.30	35.	67.5	1900	325.5	270.	307.	256.	.83
4.	.35	39.6	76.5	"	386.	306.	365.	290.	.795
5.	.40	45.	87.	1925	442.4	347.	413.	324.	.785
6.	.45	49.9	95.7	1900	487.	380.8	462.	360.	.780
7.	.50	54.2	104.6	"	531.	416.	503.	394.	.783
8.	.55	58.4	112.3	"	572.	447.	542.	423.	.780
9.	.60	62.5	119.9	"	615.	477.	582.	452.	.775
10.	.65	67.8	129.4	"	668.	516.	632.	488.	.772
11.	.70	70.8	134.7	"	698.	537.	660.	508.	.77
12.	.75	73.2	139.	1925	721.	553.	674.	517.	.766
13.	.80	75.8	143.5	"	747.	571.	697.	534.	.765
14.	.85	78.	147.5	"	769.	587.	718.	548.	.763
15.	.90	80.	#857×10 60.2	1900	789.	#857 597	746.	565.	.756
16.	.95	82.1	61.5	"	810.	609.	767.	577.	.752
17.	1.00	83.9	62.7	1910	828.	617.	780.	580.	.744

Table VII.

Double-Current Generator-Dynamic Characteristics.

Plate IV

No.	#831 ×10 D.C. Volts	#1940 D.C. Amp.	#2322 ×4 A.C. Volts	#14008 A.C. Amp.	#9082 Excit.	R.P.M.	#831 Cor. D.C. Volts	#2322 A.C. Volts ×4	Cor. A.C. Volts	Voltage Ratio A.C. ÷ D.C.
1	33.	9.	70.	13	.31	1800	330.	280.	280.	.848
2	37.2	"	74.8	"	.35	"	362.	295.2	295.	.815
3	42.2	"	82.5	"	.40	"	414.	330.0	330.	.797
4	46.9	"	90.	"	.45	"	461.	360.	358.4	.777
5	50.3	"	96.8	"	.50	"	491.	387.	385.	.783
6	52.7	"	100.08	"	.55	"	517.	400.	397.	.769
7	56.9	"	107.8	"	.60	"	557.	431.2	429.	.770
8	60.07	"	114.9	"	.65	"	590.	459.6	457.	.774
9	65.2	"	123.8	"	.70	"	640.	495.	493.	.770
10	67.2	"	127.	"	.75	"	661.	508.	506.	.765
11	69.2	"	129.	"	.80	"	680.	516.	514.	.756
12	71.	"	133.	"	.85	"	700.	532.	530.	.757
13	72.	"	134.9	"	.89	"	709.	559.6	557.	.786

Table VIII.

Direct-current Motor – Performance and Efficiency.

Plate VI.

$$Kw = \frac{R.P.M \times \text{pull in lbs.} \times \text{circ. of brake wheel in ft.} \times .746}{33000 \times 1000}$$

$$= \frac{R.P.M. \times lbs. \times 2.98 \times 0.746}{33000 \times 1000} = R.P.M. \times lbs \times 0.00067.$$

C^2R input in separately excited field $= 293$ watts.

Weston #3937 Lower Scale R.P.M. Vm.	No.	Whitney D.C. #1940 Input Amp.	Corrected as read Weston A.C. #831x10 Input Volts	Weston Mil-Am. #2724 Exc.	Scales correct. Output Brake Scale 1.	Scale 2.	Scale 1. − Scale 2.	Output Kw.	Input Volts × Amp.	Total Input Kw.	Effic.	R.P.M.
119.3	1	3.	625.	.67	#0	#0	#0	0.	1.87	2.16	0.	1800.
118.3	2	6.	"	"	15.75	3.87	11.88	1.42	3.75	4.04	.35	1780.
118.5	3	7.6	"	"	28.	5.75	22.25	2.68	4.75	5.04	.53	1788.
117.2	4	9.2	"	"	40.37	9.25	31.12	3.7	5.75	6.04	.61	1765.
118.2	5	10.9	"	"	56.	14.37	41.63	5.0	6.81	7.10	.70	1779.
118.5	6	12.2	"	"	64.	14.5	49.5	5.96	7.62	7.91	.75	1788.
118.6	7	13.5	"	"	72.5	16.5	56.0	6.75	8.44	8.73	.77	1790.
118.6	8	14.6	620.	"	80.5	19.5	61.0	7.37	9.09	9.38	.785	1790.
118.2	9	15.6	622.	"	90.25	23.1	67.15	8.06	9.67	9.96	.81	1779.
117.9	10	16.5	616.	"	97.	24.37	72.63	8.7	10.18	10.47	.83	1775.
118.	11	17.2	618.	"	102.	25.	77.0	9.23	10.62	10.91	.845	1778.
117.2	12	18.2	619.	"	109.	26.3	81.63	9.72	11.28	11.57	.84	1765.
118.	13	19.4	615.	"	114.5	28.5	86.	10.3	11.93	12.22	.84	1778.

Table IX.

Single-phase Direct Rotary

Phase Characteristics, Performance and Efficiency

Plates VII and VIII.

No.	Weston Mil-Am. #2724 Exc.	Weston A.C. Vm. #831x10 Output D.C. Volts	Whitney D.C. Am. #1940 output D.C. Amp	Weston A.C. Vm. #2322x4 Input A.C. Volts	Thomson A.C. Am. #13457 Input A.C. Amp.	Weston A.C. Wattmeter #1505x4 Input Wm.	Cor. D.C. Volts	Cor. A.C. Volts	App. Watts	P.F.	Volts x Amperes Total output Watts	True Effic.	Volt Ratio	App. Effic.
1	.35	539.	4.2	115.	19.	4000	528.	458.	8730	.458				
2	.40	547.	4.3	115.2	16.	"	535.	458.4	7340	.545				
3	.5	562.	4.5	115	11.3	"	550.	458.	5180	.77				
4	.54	570.	4.6	114.7	9.5	"	558.	456.	4330	.924				
5	.60	578.	4.5	115.2	9.3	"	566.	458.4	4270	.938	2550	.60	.81	.56
6	.65	587.	4.2	114.8	10.	"	575.	457.	4570	.865				
7	.70	602.	4.	116.	11.	"	590.	462.	5070	.79				
8	.80	623.	3.4	116.7	15.7	"	611.	464.2	7290	.55				
9	.35	529.	8.	113.2	20.5	6000	517.	450.	9220	.65				
10	.40	538.	8.	114.5	18.2	"	526.	456.	8300	.723				
11	.50	550.	7.9	114.7	14.7	"	538.	456.2	6600	.91				
12	.55	567.	7.8	115.1	13.6	"	555.	458.	6240	.962				
13	.60	575.	7.7	115.3	13.5	"	563.	458.8	6190	.97	4340	.695	.815	.675
14	.65	583.	7.5	114.5	14.4	"	571.	456.	6560	.915				
15	.705	591.	7.2	114.3	15.6	"	579.	455.8	7110	.845				
16	.80	612.	6.5	114.7	19.7	"	600.	456.2	8980	.67				
17	.35	519.	11.5	112.8	23.	8000	507.	449.	10350	.773				
18	.40	527.	11.5	113.	21.2	"	515.	450.	9540	.838				
19	.50	546.	11.4	113.3	18.3	"	534.	451.	8250	.97				
20	.55	560.	11.2	113.7	17.7	"	548.	451.5	8000	1.00				
21	.60	568.	11.	114.3	17.5	"	556.	457.	8000	1.00	6120	.742	.82	.74
22	.65	572.	10.8	113.9	18.2	"	560.	453.	8250	.97				
23	.70	585.	10.4	114.6	19.2	"	573.	456.	8750	.915				
24	.775	597.	10.	114.2	21.4	"	585.	454.2	9730	.82				
25	.36	541.	15.	113.7	27.5	10000	529.	471.5	12960	.77				
26	.40	556.	14.8	113.2	26.2	"	544.	450.5	11800	.847				
27	.50	545	14.6	113.8	22.5	"	533.	453.	10200	.98				
28	.55	552.	14.1	113.7	21.8	"	540.	451.5	10000	1.0				
29	.60	569.	13.4	116.4	21.	"	557.	463.	9750	1.025	7620	.745	.83	.745
30	.65	580.	13.3	116.8	22.	"	568.	465.	10230	.977				
31	.70	590.	13.	116.7	22.4	"	578.	463.5	10380	.964				
32	.79	606.	12.3	116.3	25.	"	594.	463.	11570	.864				
33	.494	540.	18.6	114.1	27.	12000	528.	454.	12280	.977				
34	.55	548.	17.8	113.6	26.3	"	536.	452.	11900	1.008				
35	.60	557.	16.7	113.3	25.6	"	545.	451.	11520	1.04	9100	.74	.825	.74
36	.65	572.	16.5	115.	26.5	"	560.	457.5	12100	.992				
37	.70	580.	16.3	115.	27.5	"	568.	457.5	12570	.954				
38	.60	591.	0	115.	4.7	1560	580	457.		.66	0	0	.765	0

Table X. Plates IX, X, and XI.

Inverted Rotary - Performance and Effic.

Plate IX - Curve I.

No.	Weston Mil-Am. #2724 Exc.	Weston A.C. Vm. Input #831x10 D.C. Volts.	Weston Wattmeter Output #1505x4 T. Watts	Thomson A.C. Amm. output #14010 A.C. Amp.	Weston A.C. Vm. output #2931 A.C. Volts.	Weston D.C. Vm. Lower Scale R.P.M. #3937	App. Watts.	P.F.
1	0.73	625	4000	13.	473.	1660.	6150	Lead .65
2	"	"	"	12.	470.	1688.	5640	.71
3	"	"	"	10.5	463.	1702.	4870	.822
4	"	"	"	9.	464.	1755.	4185	.956
5	"	"	"	9.	464.	1768.	4180	.96
6	"	"	"	8.9	461.	1790.	4060	.985
7	"	"	"	9.6	454.	1822.	4360	Lag .92
8	"	"	"	9.	459.	1850.	4130	.97(?)
9	"	"	"	10.7	455.	1883.	4870	.82
10	"	"	"	12.	448.	1932.	5370	.745
11	"	"	"	13.5	444.	1970.	6000	.666

Curve II.

1	0.58	625	4000	15.	481.6	1807.	7220	Lead .554
2	0.61	"	"	12.	475.2	"	5690	.700
3	0.655	"	"	10.	468.4	"	4684	.865
4	0.700	"	"	8.8	462.8	"	4070	.983
5	0.745	"	"	9.8	457.2	"	4480	Lag .892

Plate X

No.	Input #1940 D.C. Amp.	Input #831x10 D.C. Volts	output #2931 A.C. Volts	output #13457 A.C. Amp.	output #1505x4 T. Watts	R.P.M.	#2724 Exc.	Total Input Watts	Effic.	P.F.	Volt Ratio
1	5.	625.	482.	5.	1200.	1830	.59	3305.	.363	Lead .50	.77
2	8.5	"	478.	8.	2880.	"	.60	5490.	.525	.77	.765
3	10.5	"	476.	11.	4320.	"	.615	6740.	.640	.825	.76
4	13.5	"	478.	14.7	6240.	"	.63	8620.	.725	.894	.765
5	16.6	"	469.	17.5	8000.	"	.64	10560.	.76	.975	.735
6	21.5	"	444.	24.5	10000.	"	.63	13620.	.735	.915	.71

Plate XI

1	5.3	625	478.5	4.5	930	1832	0.600	3500	.266	Lead .43	.765
2	6.2	"	479.5	5.5	1660	1827	"	4060	.41	.63	.767
3	7.1	"	480.5	6.4	2240	1827	"	4620	.485	.73	.77
4	8.5	"	478.5	8.0	3100	1825	"	5490	.565	.81	.765
5	10.0	"	477.5	10.2	4140	1817	"	6430	.645	.85	.764
6	11.2	"	469.5	11.5	4760	1818	"	7180	.6630	.865	.764
7	12.8	"	467.5	13.	5760	1861	"	8180	.705	.945	.75
8	14.0	"	461.5	14.5	6560	1854	"	8930	.735	.97	.747
9	15.6	"	4[illegible]1.5	16.6	7640	1910	"	9930	.77	1.00	.737
10	18.4	"	459.5	20.	8960	1910	"	11680	.77	Lag .973	.735
11	19.8	"	453.5	21.2	9520	1952	"	12580	.76	.99	.725

Table XI.

Single-phase Synchronous Motor.

Phase Characteristics – Performance and Efficiency.

Plates XII and XIII.

Kw. = R.P.M. x Pull in lbs. x .000067

	Weston Mil.Am.	Weston	Thomson	Weston Wattmeter			Weston D.C. Vm. #3937						
No.	#2724 Exc.	#2931 x4 Input A.C. Volts	#13457 Input A.C. Amp.	#1500 x4 Input T. Watts	App. Watts.	P.F.	R.P.M.	Output Scale 1.	Output Scale 2.	Scale 1. − Scale 2.	Output Watts	Effic.	Total Input Watts
1	.35	457.	17.8	4000	8150	.49							
2	.40	458.	15.7	"	7190	.56							
3	.50	459.6	11.2	"	5190	.78							
4	.55	462.	9.5	"	4380	.91							
5	.60	462.	9.	"	4150	.96	1800	21.#	4.5	16.5	1985	.47	4240
6	.65	458.	9.6	"	4400	.91							
7	.70	465.	11.	"	5120	.78							
8	.80	468.	15.	"	6970	.57							
9	.35	458.	20.3	6000	9300	.645							
10	.40	461.	17.9	"	8260	.73							
11	.50	462.	14.4	"	6650	.90							
12	.55	463.	13.4	"	6210	.965							
13	.60	465.	12.8	"	5950	1.00	1785	39.2	8.5	30.7	3680	.585	6240
14	.65	464.	13.3	"	6170	.97							
15	.70	465.	14.2	"	6600	.91							
16	.80	468.	17.4	"	8140	.74							
17	.35	454.	23.2	8000	10560	.76							
18	.40	455.	21.2	"	9650	.83							
19	.50	457.	18.3	"	8360	.96							
20	.55	457.	17.2	"	7860								
21	.60	458.	16.7	"	7670		1770	59.2	11.2	48.	5700	.69	8240
22	.65	459.	17.	"	7820								
23	.70	463.	17.8	"	8240	.97							
24	.80	467.	20.3	"	9500	.84							
25	.35	458.	26.8	10000	12280	.815							
26	.40	460.	25.2	"	11600	.86							
27	.50	464.	22.	"	10200	.98							
28	.55	462.	20.7	"	9550								
29	.60	467.	20.7	"	9650	—	1770	74.	11.9	62.1	7360	.717	10240
30	.65	468.	20.3	"	9500								
31	.70	468.	21.	"	9840								
32	.80	469.	23.	"	10800	.925							
33	.60	460.	26.2	12000	12000	1.00	1750	90.	12.5	77.5	9100	.745	12240

Table XII.

Single-phase Rotary - No-load phase characteristics

Plate XIV.

Curves III to VIII inclusive.

No.	Weston Mil-Am. #2724 Exc.	Weston A.C. Vm. #83/x10 D.C. Volts	Weston A.C. Vm. #2931 x4 A.C. Volts	Thomson A.C. Am. #13457 Input A.C. Amp.	Weston A.C. Wm. #1500x4 Input T. Watts	Weston D.C. Vm. #3937. R.P.M.	Cor. D.C. Volts	A.C. Volts	App. Watts	True Watts	P.F.
1	0.33	545	114.3	18.2	.46	1800	533.	457.	8300.	1840.	.22
2	0.35	550	114.8	17.	.44	"	538.	459.	7800.	1760.	.23
3	0.40	558	115.1	14.4	.42	"	546.	460.	6600.	1680.	.25
4	0.50	578	115.8	8.8	.38	"	566.	463.	4100.	1520.	.37
5	0.55	588	116.	6.	.38	"	576.	464.	2780.	1520.	.55
6	0.60	598	116.2	4.7	.39	"	586.	465.	2180.	1560.	.72
7	0.65	610	116.5	5.7	.41	"	598.	466.	2660.	1640.	.62
8	0.70	618	117.2	7.8	.43	"	606.	469.	3660	1720.	.47
9	0.75	628	117.1	9.9	.47	"	616.	468.	4650.	1880.	.40
10	0.80	637	117.5	13.	.51	"	625.	470.	6100.	2040.	.33
11	0.85	648	117.7	15.5	.56	"	636.	471.	7300.	2240.	.31
12	0.875	653	117.8	17.	.60	"	641.	471.	8000.	2400.	.30

Curve I.

Weston A.C. Vm. #2882 x4. A.C. Volts	No.	#2724 Weston Mil-Ammeter Exc.	Whitney D.C. Am. #1940 D.C. Amperes in Series Coils.	Thomson A.C. Ammeter No. 19008. A.C. Amperes Input
113.6	1	0.4	0.	15.
113.3	2	0.4	4.5	13.2
113.8	3	"	6.6	12.6
"	4	"	9.3	11.6
"	5	"	12.6	10.3
113.7	6	"	15.9	9.
113.8	7	"	20.6	7.6
"	8	"	25.	6.3
"	9	"	26.5	5.9
114.1	10	"	0.	15.5

Curve II.

114.3	1	0.6	0.	5.7
"	2	"	6.5	6.5
"	3	"	9.5	7.3
"	4	"	11.8	8.2
"	5	"	14.3	8.9
"	6	"	18.6	10.7
"	7	"	22.4	11.8
"	8	"	26.5	13.3

Table XIII.

Single-phase Rotary-No-load Regulation Characteristics

Plate XV.

No.	Weston G.C. Vm. #2882. A.C. Volts at Gen.	Weston A.C. Vm. #2322 A.C. Volts at rotary	Thomson A.C. Am #14008 Input A.C. Amperes	Weston Wattmeter #1500x4 Input T. Watts.	Weston Mil-Ammeter #2724 Exc.	Weston A.C. Vm. #831x10 D.C. Volts
1	113.8	87.	3.8	.29	.42	446
2	114.	96.7	4.1	.32	.5	500
3	"	103.6	4.5	.32	.55	537
4	"	108.2	4.7	.38	.60	563
5	"	113.3	5.1	.40	.65	591
6	"	118.6	5.5	.44	.70	621
7	"	122.9	5.9	.47	.75	644
8	114.2	126.7	6.3	.51	.80	667

No.	A.C. volts at Gen.	A.C. volts at rotary	A.C. Amp.	app. Watts.	True Watts	Exc.	P.F.	D.C. volts.	volt Ratio.
1	457	348.	3.8	1322	1160.	.42	.88	446.	.777
2	"	387.	4.1	1570	1280.	.50	.815	500.	.774
3	"	414.	4.5	1864	1280.	.55	.69	537.	.771
4	"	433.	4.7	2040	1520.	.60	.745	563.	.769
5	"	453.	5.1	2310	1600.	.65	.69	591.	.767
6	"	474.	5.5	2610	1760.	.70	.675	621.	.763
7	"	492.	5.9	2900	1880.	.75	.65	644.	.763
8	"	507.	6.3	3190	2090.	.80	.64	667.	.760

Table XIV.

Resistance Data. (Hot.)

Shunt Field

	Weston Mil-ammeter #2724.	Weston A.C. Voltmeter #2322 X4			Ohms	Ohms.
No.	Amperes	Volts	Original Volts	Corrected Volts	Resistance	Mean
1.	0.82	125.5	502.0	500.	610.	
2.	.75	115.8	463.2	461.	615.	
3.	.70	118.5	474.0	472.	674.	
4.	.59	92.3	369.2	368.	623.	
5.	.50	78.9	315.6	314.	628.	
6.	.40	63.7	254.8	254.	635.	
7.	.30	49.2	196.8	196.	653.	635.

Armature, Including Brush-contact.

No.	Amperes	Weston D.C. Voltmeter #4350	Original Volts	Corrected Volts	Resistance	Mean
1.	0.900	169.	0.845	—	.94	
2.	0.590	113	.565	—	.956	
3.	.590	104	.520	—	.882	
4.	.900	159	.795	—	.884	
5.	.900	143.5	.717	—	.799	
6.	.500	80.	.40	—	.800	
7.	.500	82.	.41	—	.82	
8.	1.350	234.	1.17	—	.865	
9.	1.345	217.	1.07	—	.87	
10.	.495	80.	.40	—	.807	0.86

Armature, Under Brushes.

No.	Amperes	Weston D.C. Vm. No. 3937	Original Volts.	Corrected Volts	Resistance	Mean
1.	0.495	11.1	10.5 ÷ 30	0.35	0.708	
2.	1.11	24.2	23.2	.775	.698	
3.	1.11	24.	23.1	.77	.693	
4.	1.41	30.	29.3	.975	.693	
5.	1.40	196. #4353	198. ÷ 200	.99	.707	
6.	.696	95.	95.	.475	.682	
7.	.688	93.	93.	.465	.677	
8.	.400	55.	55.	.275	.688	
9.	.400	55.	55.	.275	.688	
10.	1.300	175.	176.	.88	.677	0.69

Series Field.

No.	Amperes	Weston D.C. Vm. #4353	Original Volts	Corrected Volts	Resistance	Mean
1.	1.44	80. ÷ 200	81. ÷ 200	0.401	0.278	
2.	1.20	67.	68.	.34	.283	
3.	.94	52.	53.	.265	.282	
4.	.74	40.	41.	.205	.277	
5.	1.49	80.	81.	.401	.269	0.278

Plate I.

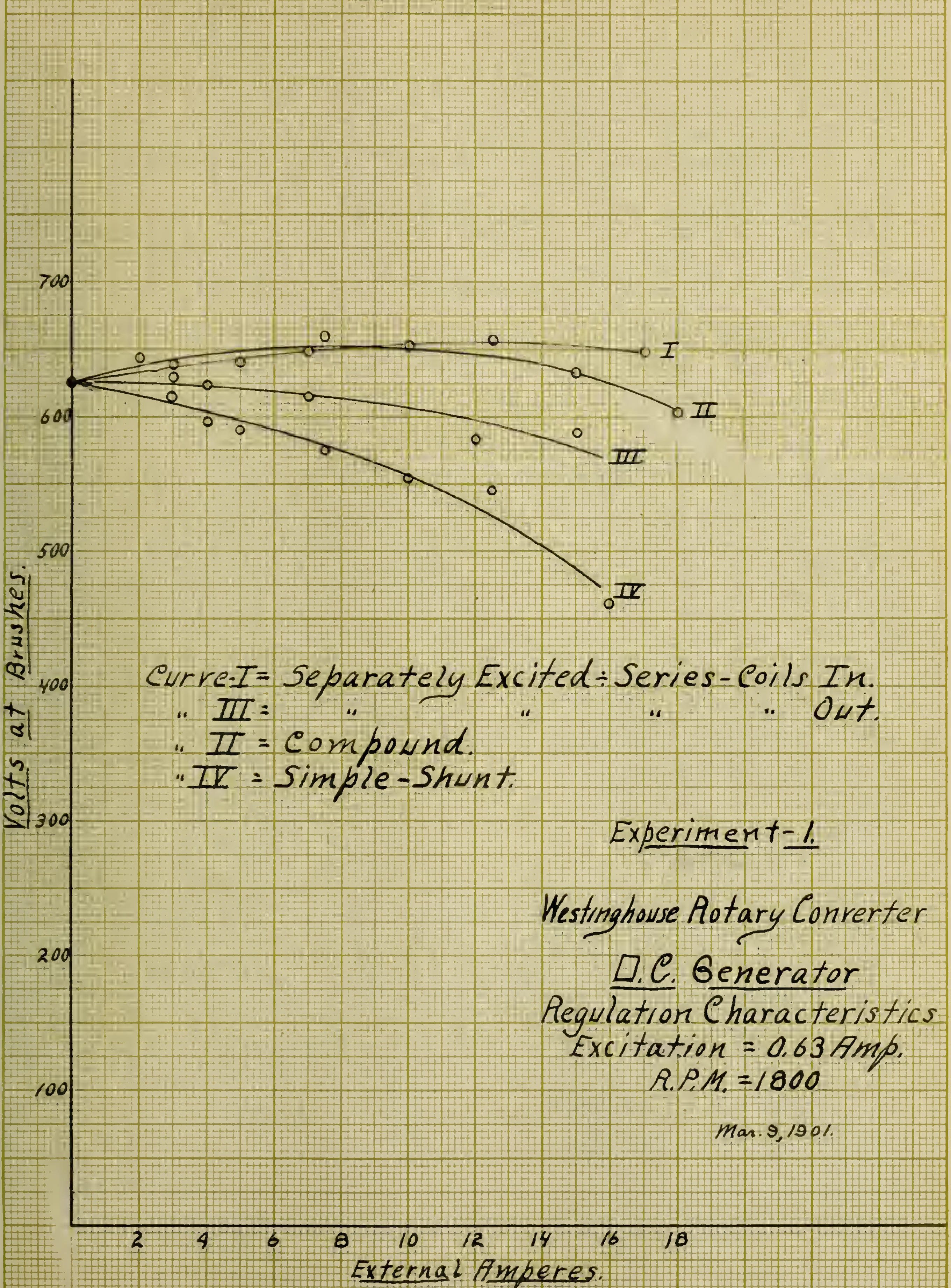
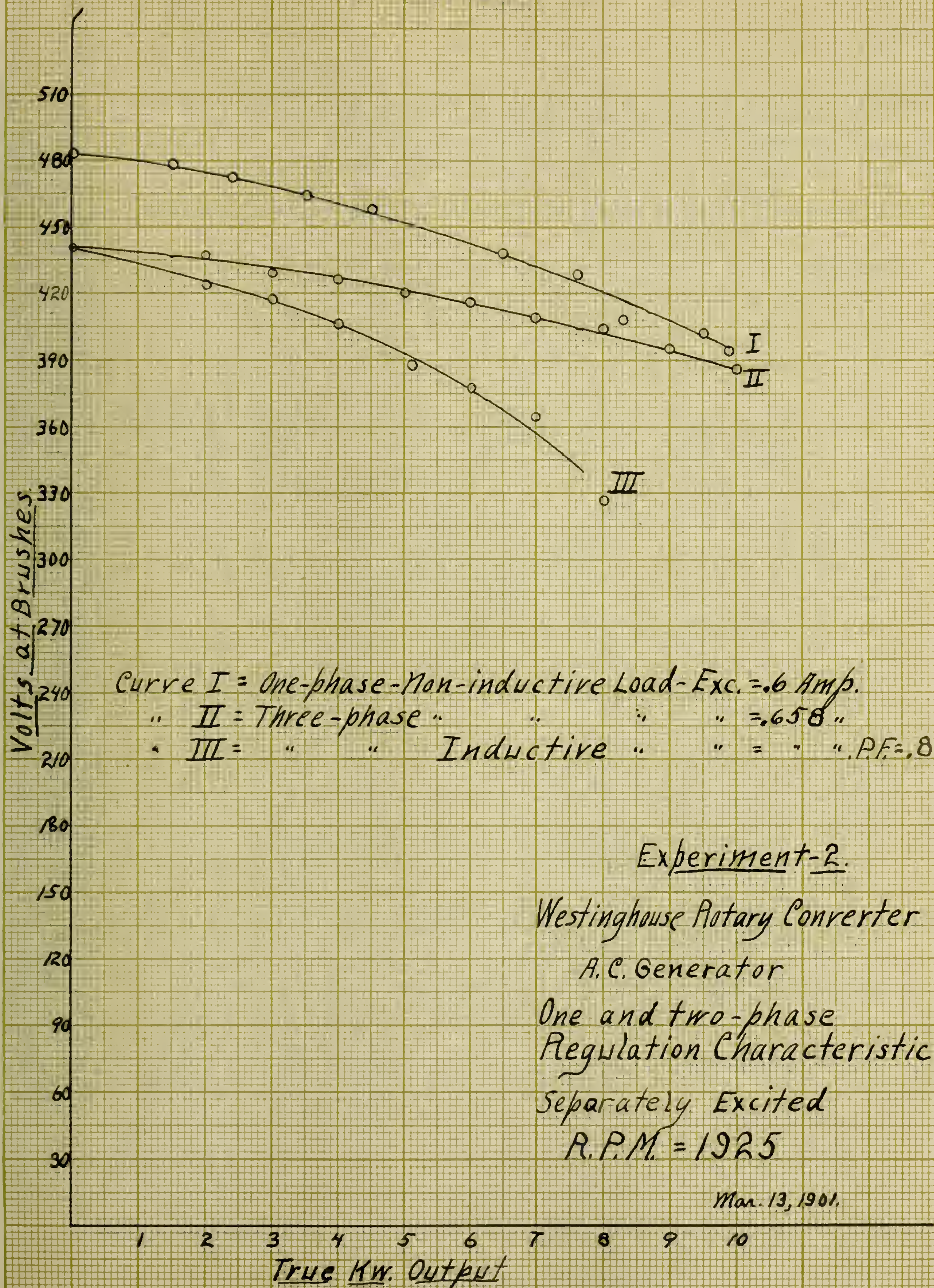

700
600
500
400
300
200
100
Volts at Brushes.
2
4
6
8
10
12
14
16
18
External Amperes.
I
II
III
IV
Curve-I = Separately Excited - Series-Coils In.
" III = " " " " Out.
" II = Compound.
" IV = Simple-Shunt.
Experiment-1.
Westinghouse Rotary Converter
D.C. Generator
Regulation Characteristics
Excitation = 0.63 Amp.
R.P.M. = 1800
Mar. 9, 1901.

Plate II.


Volts at Brushes
510
480
450
420
390
360
330
300
270
240
210
180
150
120
90
60
30
I
II
III
Curve I = One-phase-Non-inductive Load-Exc. = .6 Amp.
" II = Three-phase " " " " = .658 "
" III = " " Inductive " " = " ". P.F. = .8
Experiment-2.
Westinghouse Rotary Converter
A. C. Generator
One and two-phase
Regulation Characteristic
Separately Excited
R.P.M. = 1925
Mar. 13, 1901.
1
2
3
4
5
6
7
8
9
10
True Kw. Output

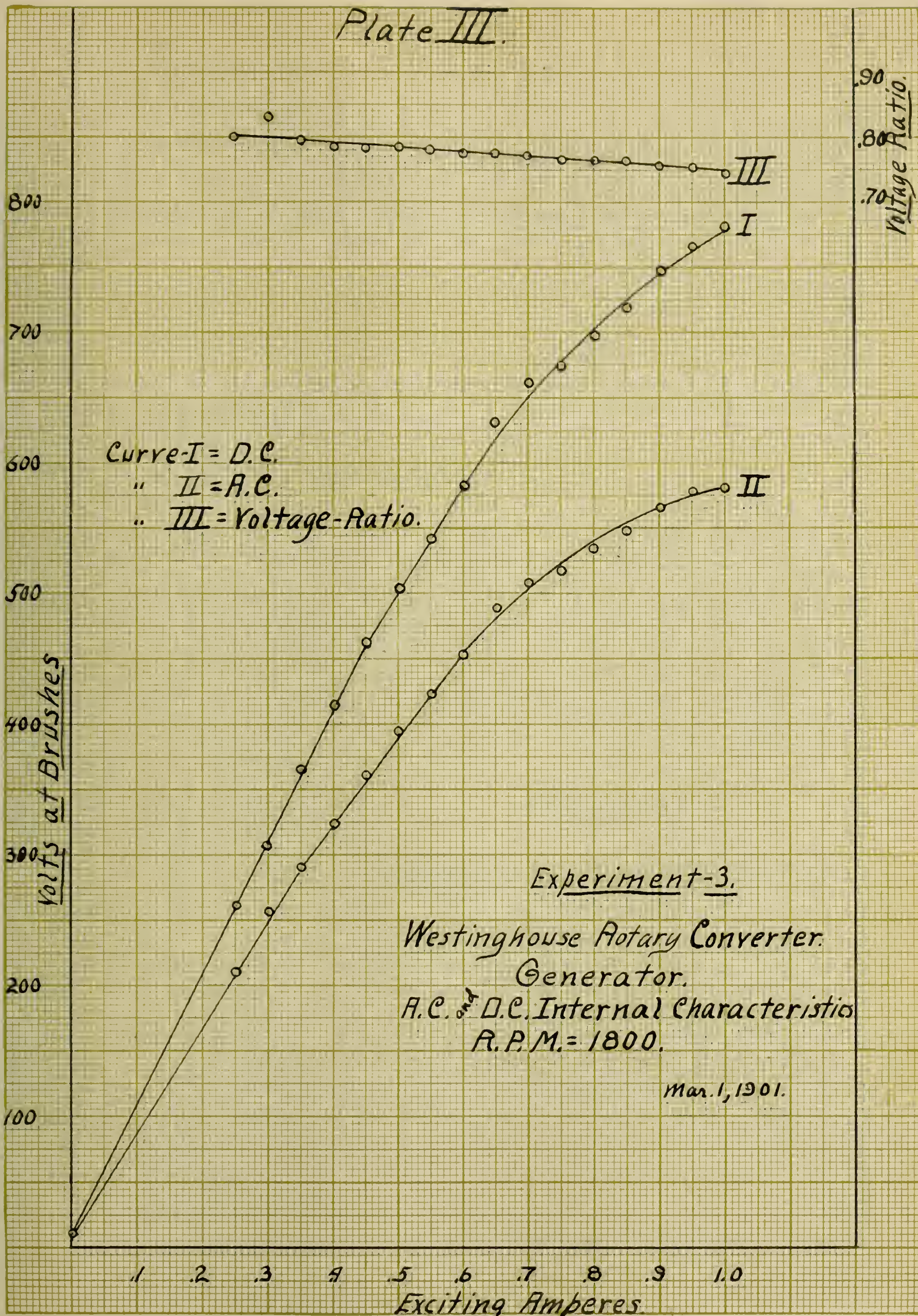


Plate III.
Voltage Ratio.
.90
.80
.70
800
700
600
500
400
300
200
100
Volts at Brushes
III
I
II
Curve-I = D.C.
" II = A.C.
" III = Voltage-Ratio.
Experiment-3.
Westinghouse Rotary Converter.
Generator.
A.C. and D.C. Internal Characteristics
R.P.M. = 1800.
Mar. 1, 1901.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
Exciting Amperes.

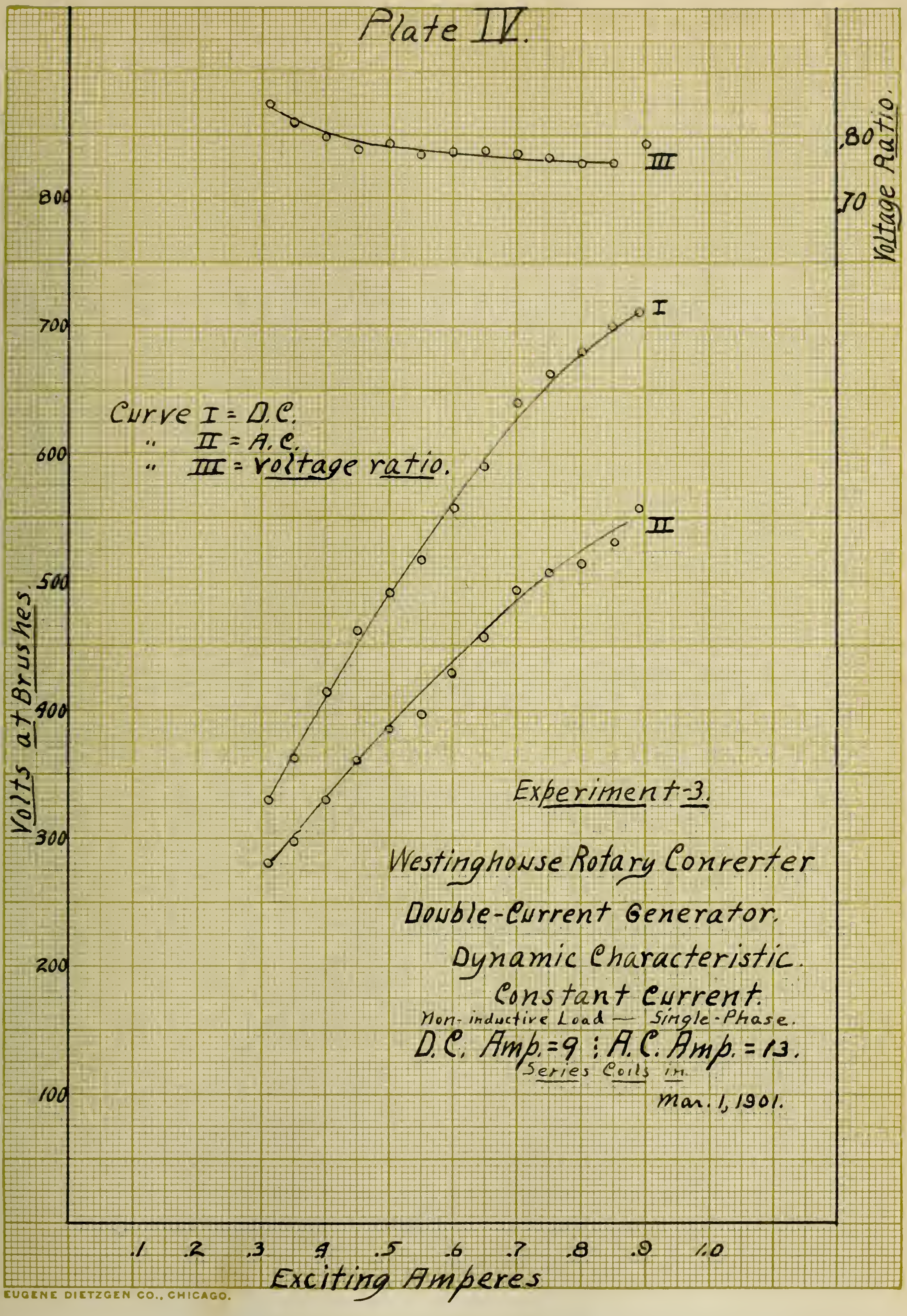
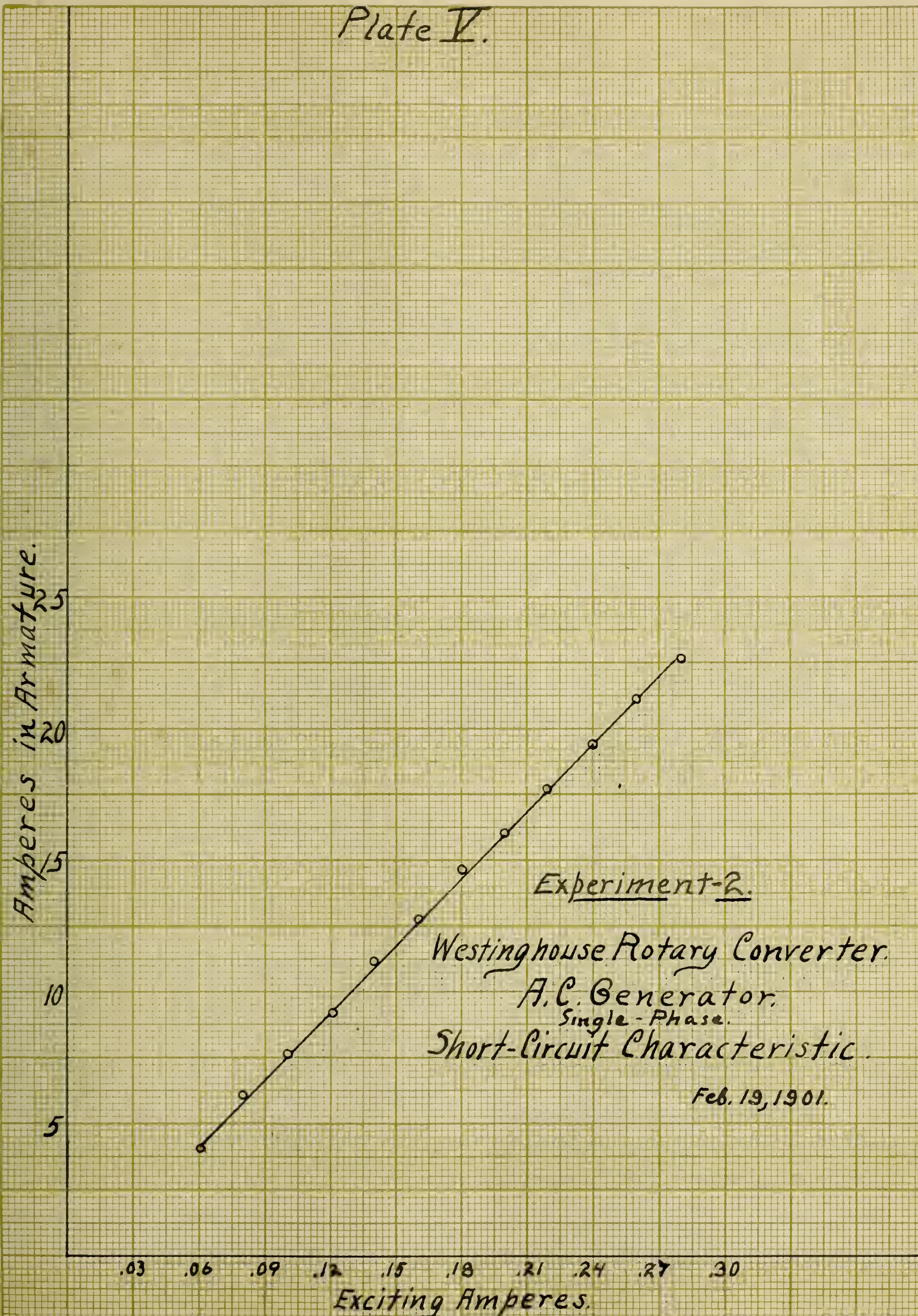


Plate IV.
800
700
600
500
400
300
200
100
.80
.70
Voltage Ratio.
Volts at Brushes.
III
I
II
Curve I = D.C.
" II = A.C.
" III = Voltage ratio.
Experiment-3.
Westinghouse Rotary Converter
Double-Current Generator.
Dynamic Characteristic.
Constant Current.
Non-inductive Load — Single-Phase.
D.C. Amp.=9 ; A.C. Amp. = 13.
Series Coils in.
Mar. 1, 1901.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
Exciting Amperes
EUGENE DIETZGEN CO., CHICAGO.

Plate V.



EUGENE DIETZGEN CO., CHICAGO.

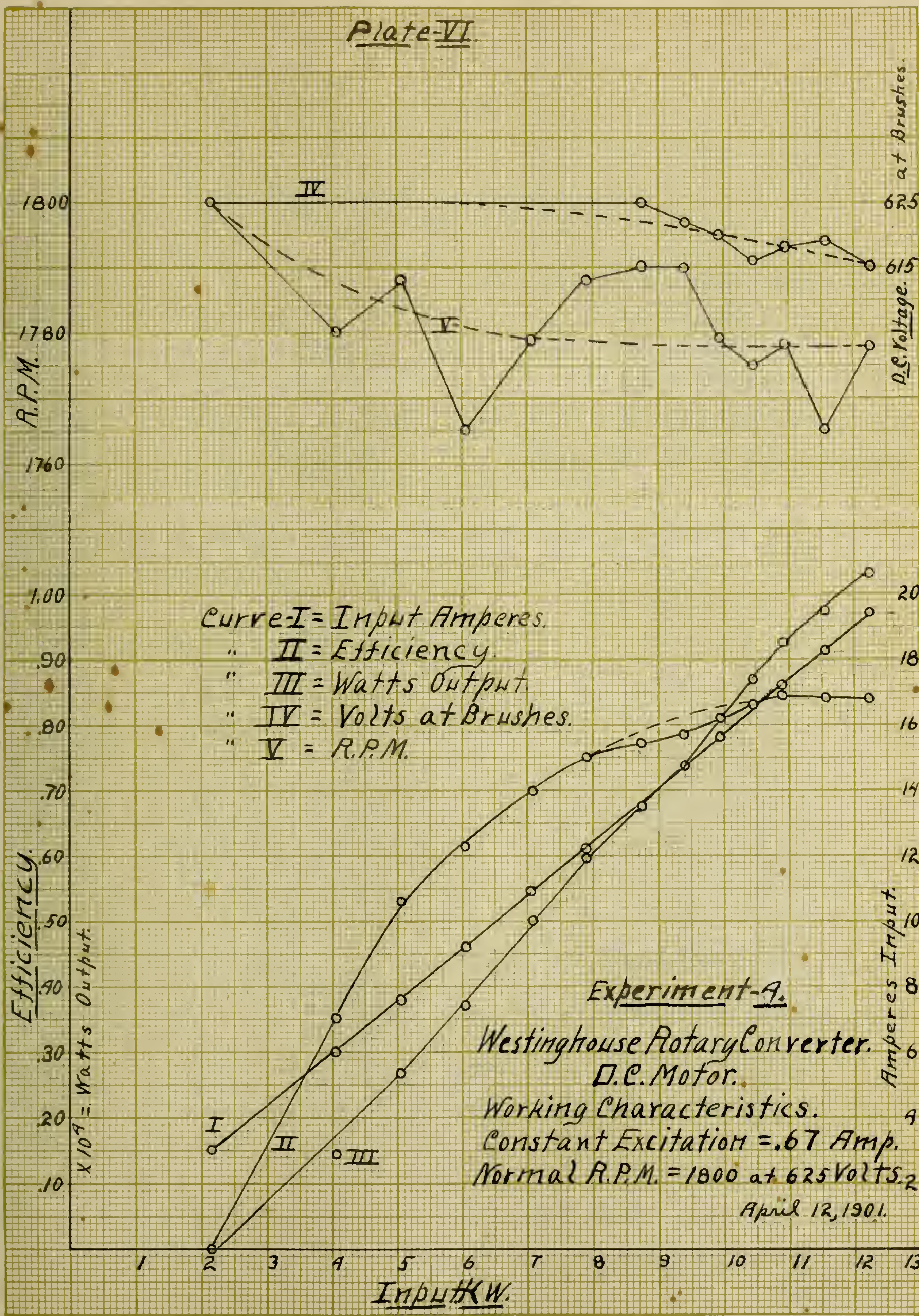


Plate-VI.
IV
V
R.P.M.
1800
1780
1760
625
615
D.C. Voltage. at Brushes.
Curve-I = Input Amperes.
" II = Efficiency.
" III = Watts Output.
" IV = Volts at Brushes.
" V = R.P.M.
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
Efficiency.
X 10^4 = Watts Output.
20
18
16
14
12
10
8
6
4
2
Amperes Input.
Experiment-4.
Westinghouse Rotary Converter.
D.C. Motor.
Working Characteristics.
Constant Excitation = .67 Amp.
Normal R.P.M. = 1800 at 625 Volts.
April 12, 1901.
I
II
III
1
2
3
4
5
6
7
8
9
10
11
12
13
Input K.W.
EUGENE DIETZGEN CO., CHICAGO.

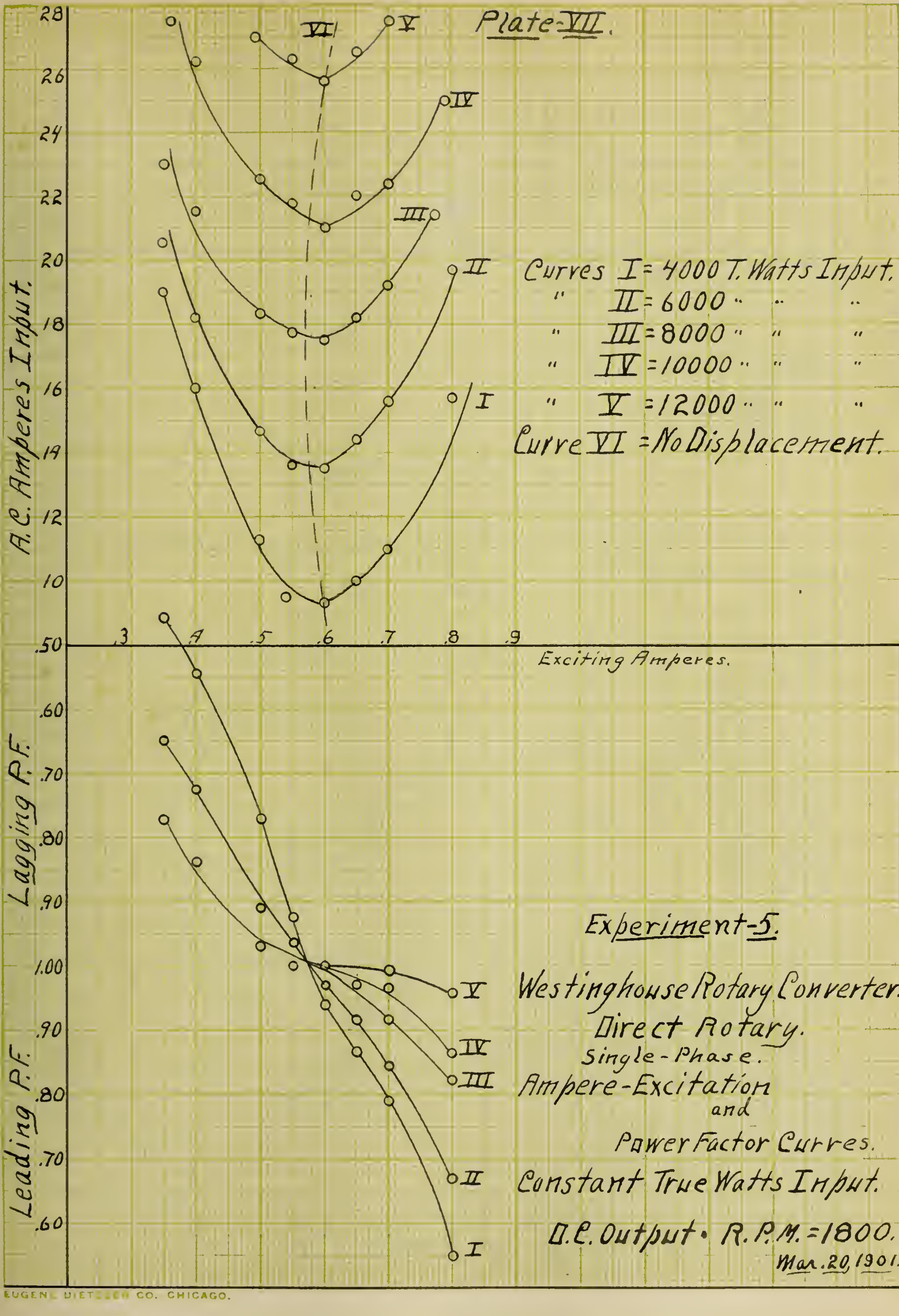
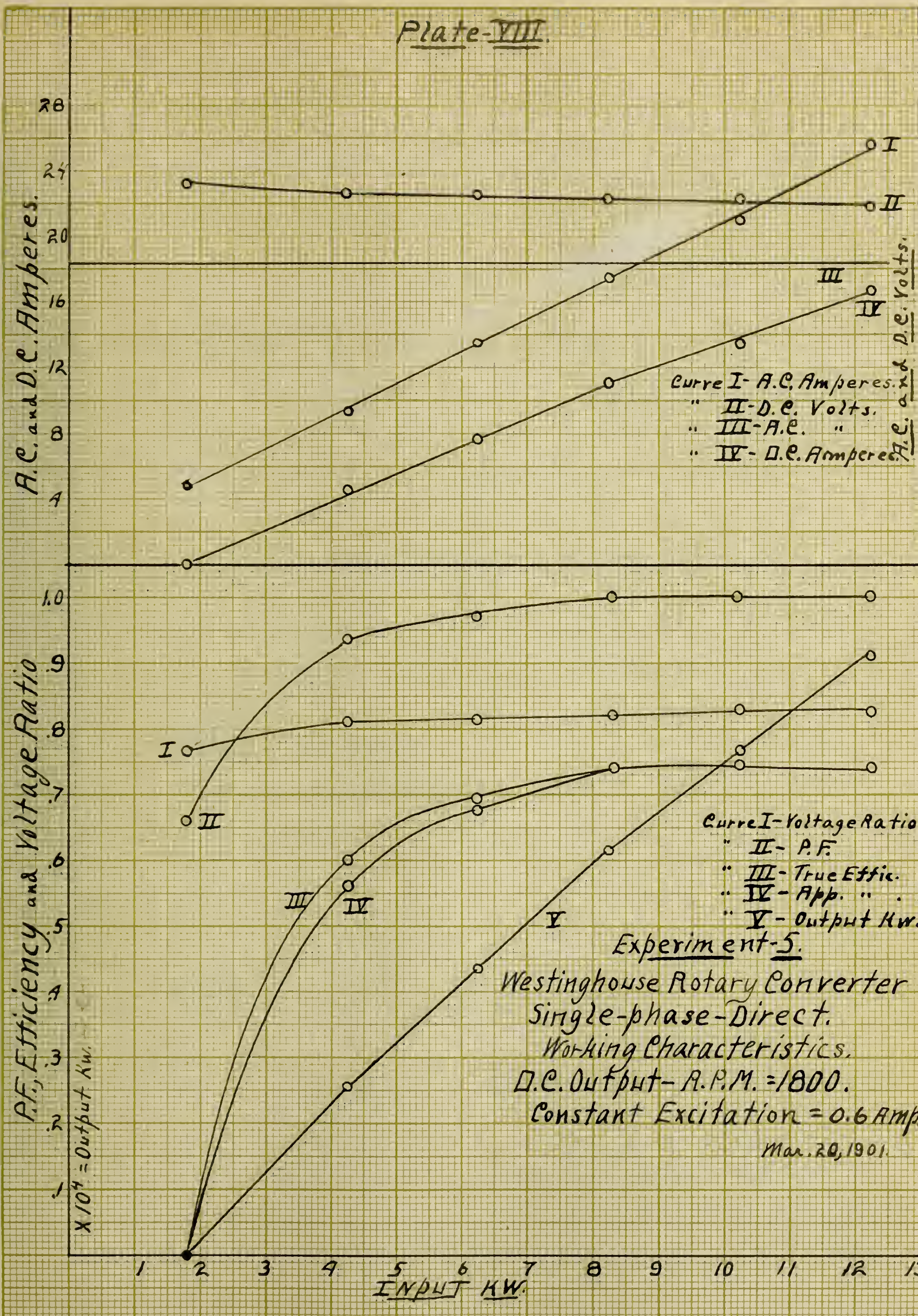


Plate-VII.
A.C. Amperes Input.
Lagging P.F.
Leading P.F.
Exciting Amperes.
Curves I = 4000 T. Watts Input.
" II = 6000 " " "
" III = 8000 " " "
" IV = 10000 " " "
" V = 12000 " " "
Curve VI = No Displacement.
Experiment-5.
Westinghouse Rotary Converter.
Direct Rotary.
Single-Phase.
Ampere-Excitation
and
Power Factor Curves.
Constant True Watts Input.
D.C. Output. R.P.M. = 1800.
Mar. 20, 1901.
EUGENE DIETZGEN CO. CHICAGO.



EUGENE DIETZGEN CO., CHICAGO.

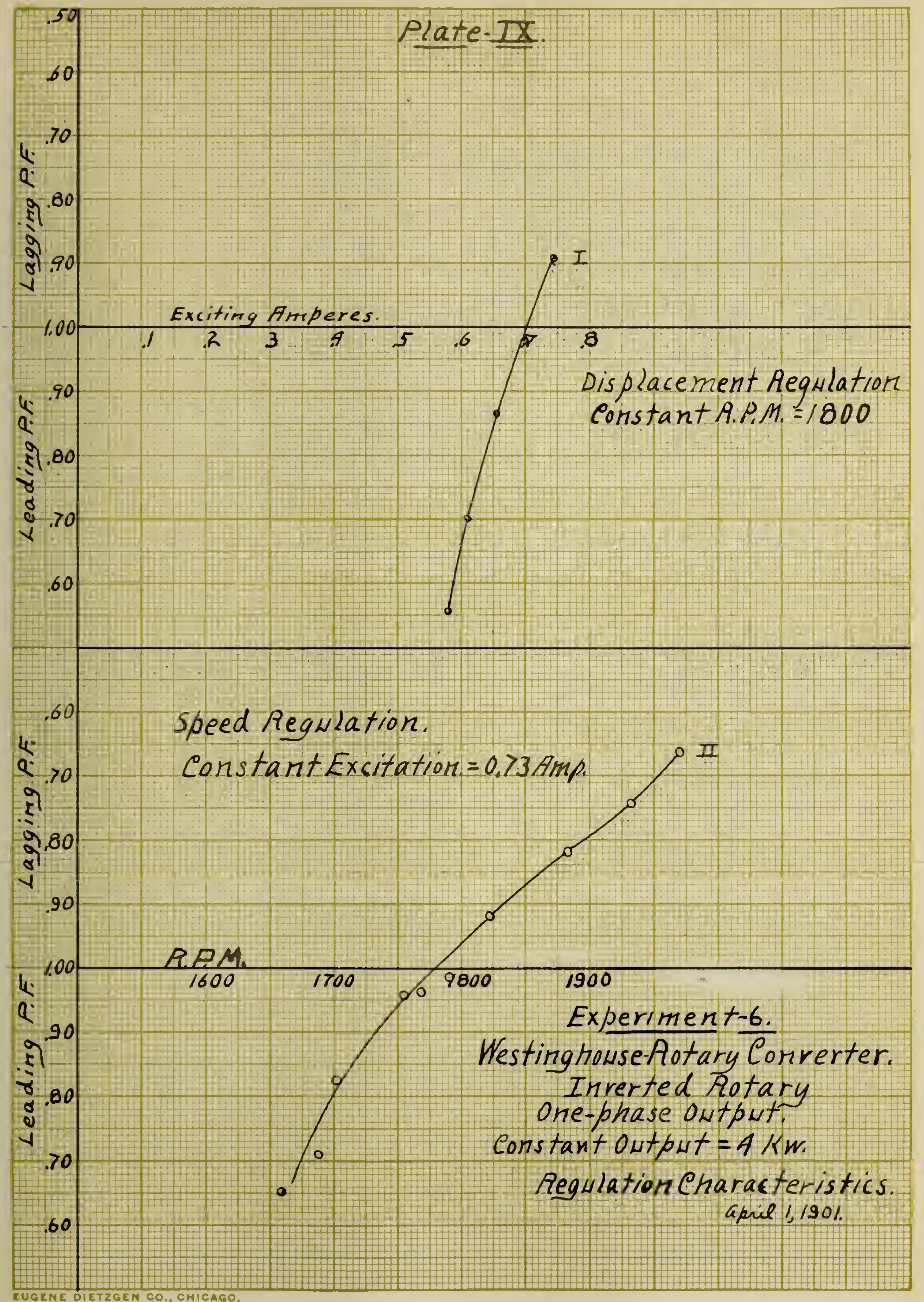


Plate-IX.
Lagging P.F.
Leading P.F.
.50
.60
.70
.80
.90
1.00
Exciting Amperes.
.1
.2
.3
.4
.5
.6
.7
.8
I
Displacement Regulation
Constant R.P.M. = 1800
Speed Regulation.
Constant Excitation = 0,73 Amp.
II
R.P.M.
1600
1700
1800
1900
Experiment-6.
Westinghouse Rotary Converter.
Inverted Rotary
One-phase Output.
Constant Output = 4 Kw.
Regulation Characteristics.
April 1, 1901.

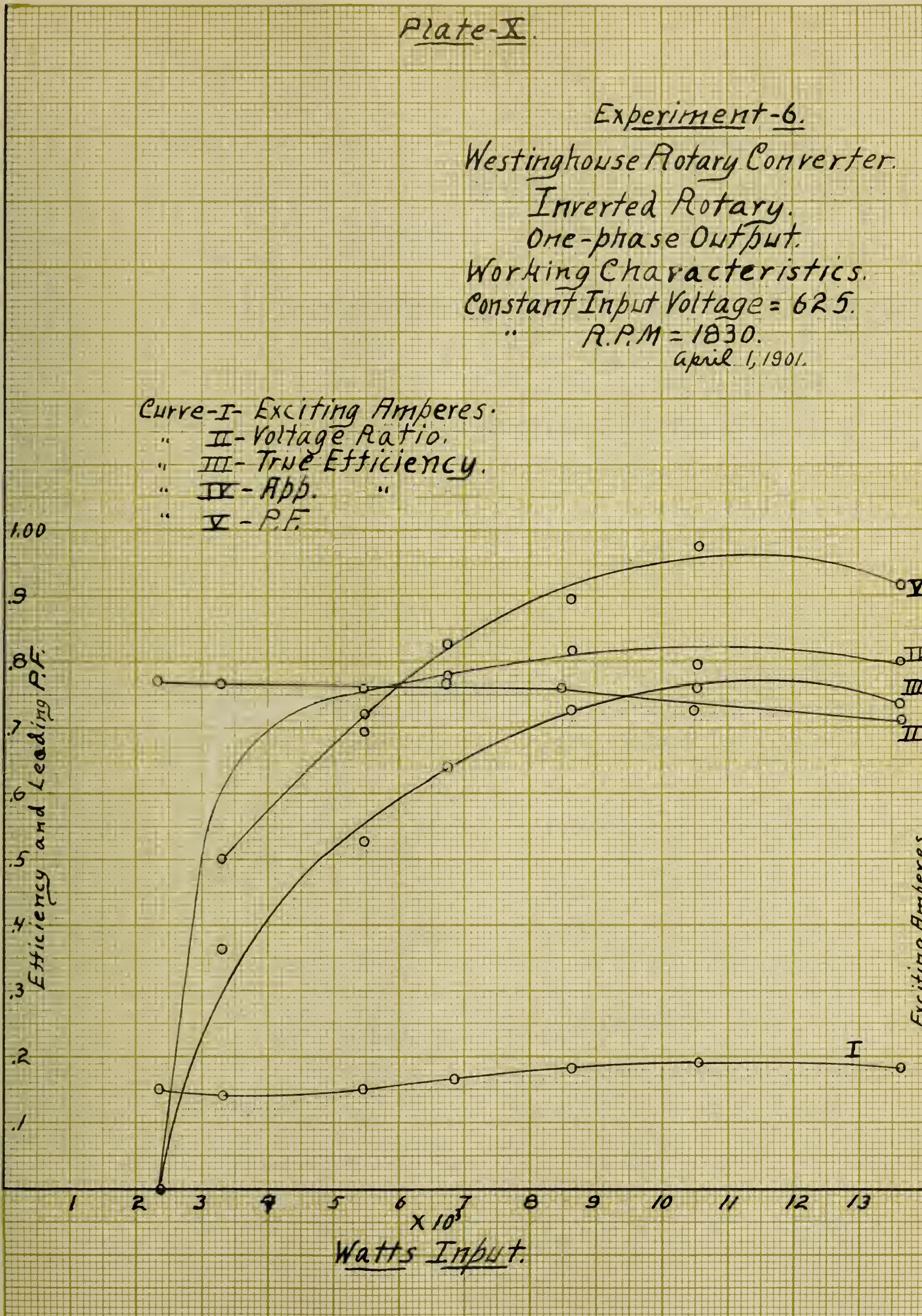
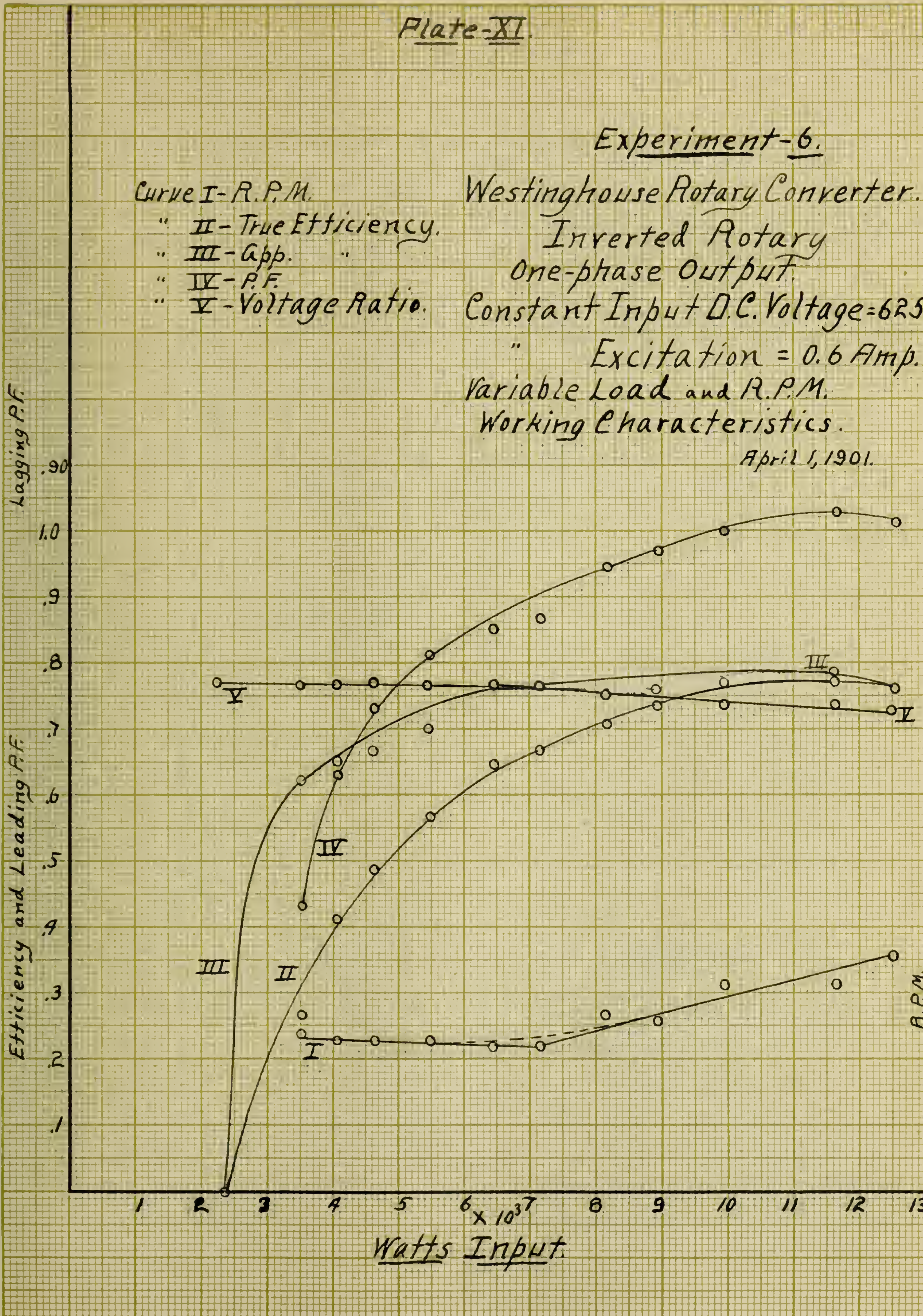


Plate-X.
Experiment-6.
Westinghouse Rotary Converter.
Inverted Rotary.
One-phase Output.
Working Characteristics.
Constant Input Voltage = 625.
" R.P.M = 1830.
April 1, 1901.
Curve-I- Exciting Amperes.
" II- Voltage Ratio.
" III- True Efficiency.
" IV- App. "
" V- P.F.
Efficiency and Leading P.F.
Exciting Amperes.
1.00
.9
.8
.7
.6
.5
.4
.3
.2
.1
.65
.55
I
II
III
IV
V
1
2
3
4
5
6
7
8
9
10
11
12
13
X 10³
Watts Input.



EUGENE DIETZGEN CO., CHICAGO.

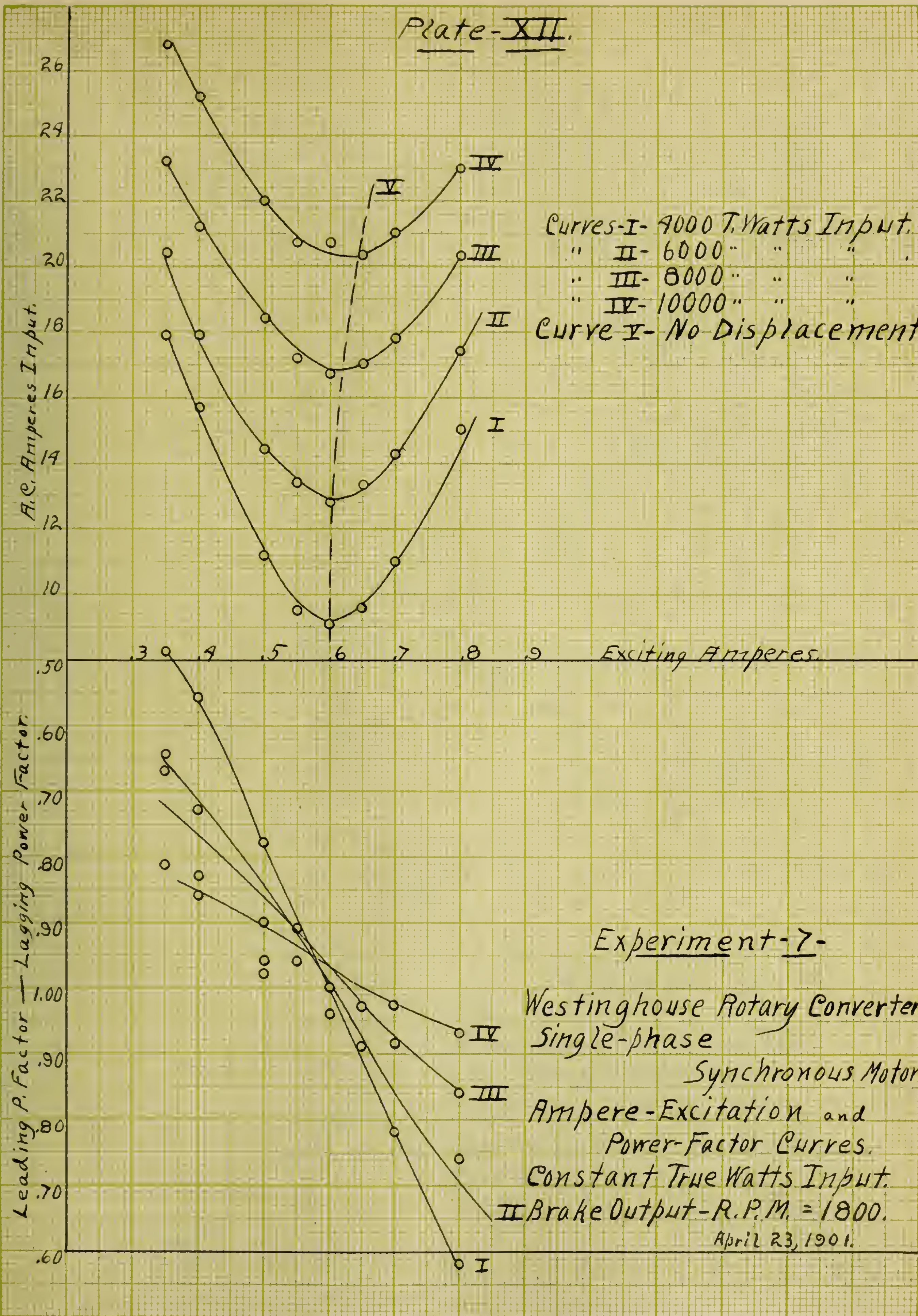


Plate-XII.
Curves-I- 4000 T. Watts Input.
" II- 6000 " " "
" III- 8000 " " "
" IV- 10000 " " "
Curve V- No Displacement.
A.C. Amperes Input.
26
24
22
20
18
16
14
12
10
.3
.4
.5
.6
.7
.8
.9
Exciting Amperes.
I
II
III
IV
V
Leading P. Factor — Lagging Power Factor.
.50
.60
.70
.80
.90
1.00
.90
.80
.70
.60
Experiment-7-
Westinghouse Rotary Converter.
Single-phase
Synchronous Motor
Ampere-Excitation and
Power-Factor Curves.
Constant True Watts Input.
II Brake Output-R.P.M. = 1800.
April 23, 1901.

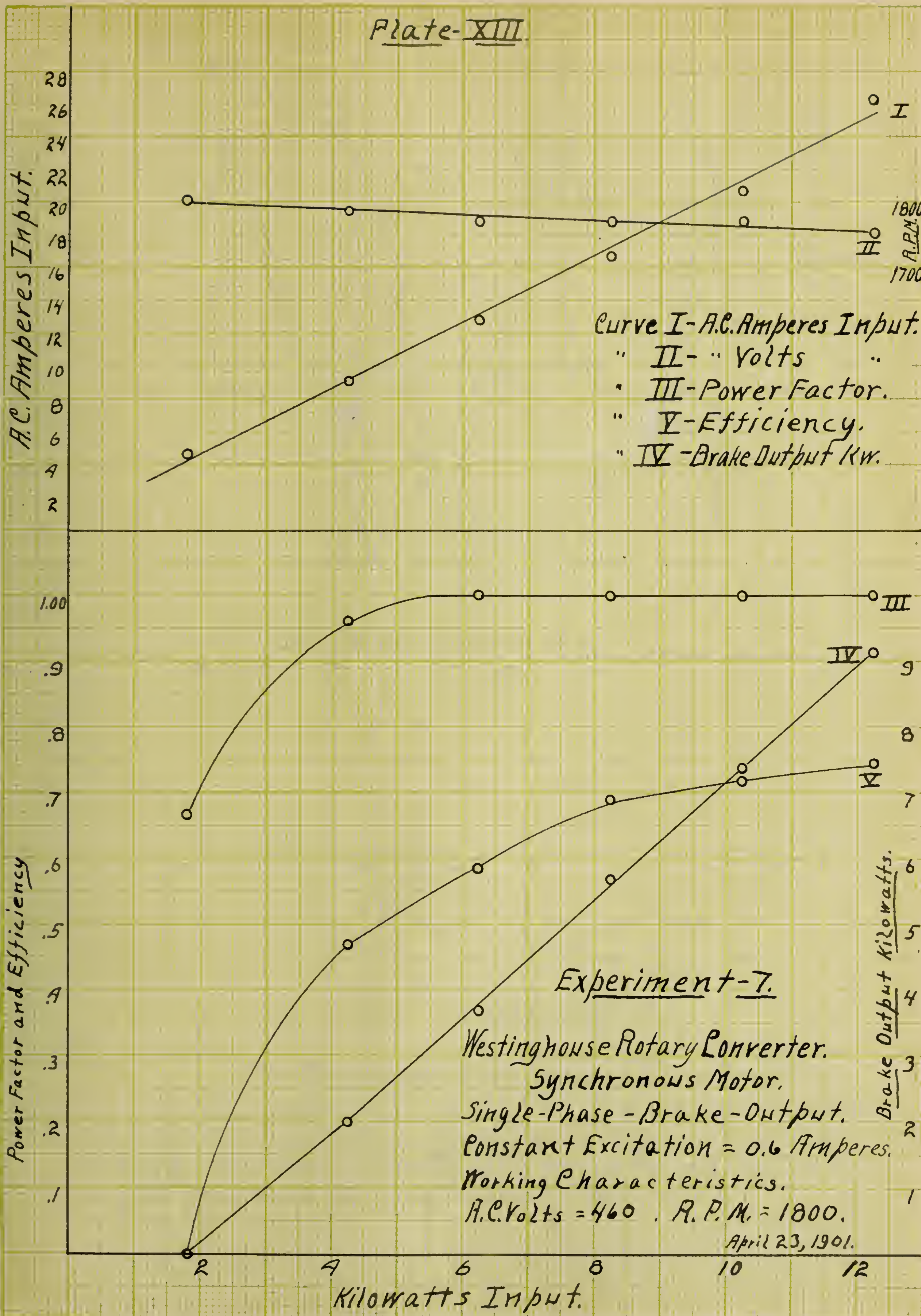


Plate-XIII.
A.C. Amperes Input.
28
26
24
22
20
18
16
14
12
10
8
6
4
2
I
1800
II
R.P.M.
1700
Curve I-A.C. Amperes Input.
" II- " Volts "
" III-Power Factor.
" V-Efficiency.
" IV -Brake Output Kw.
Power Factor and Efficiency
1.00
.9
.8
.7
.6
.5
.4
.3
.2
.1
III
IV
V
Brake Output Kilowatts.
9
8
7
6
5
4
3
2
1
Experiment-7.
Westinghouse Rotary Converter.
Synchronous Motor.
Single-Phase - Brake-Output.
Constant Excitation = 0.6 Amperes.
Working Characteristics.
A.C. Volts = 460 . R.P.M. = 1800.
April 23, 1901.
2
4
6
8
10
12
Kilowatts Input.

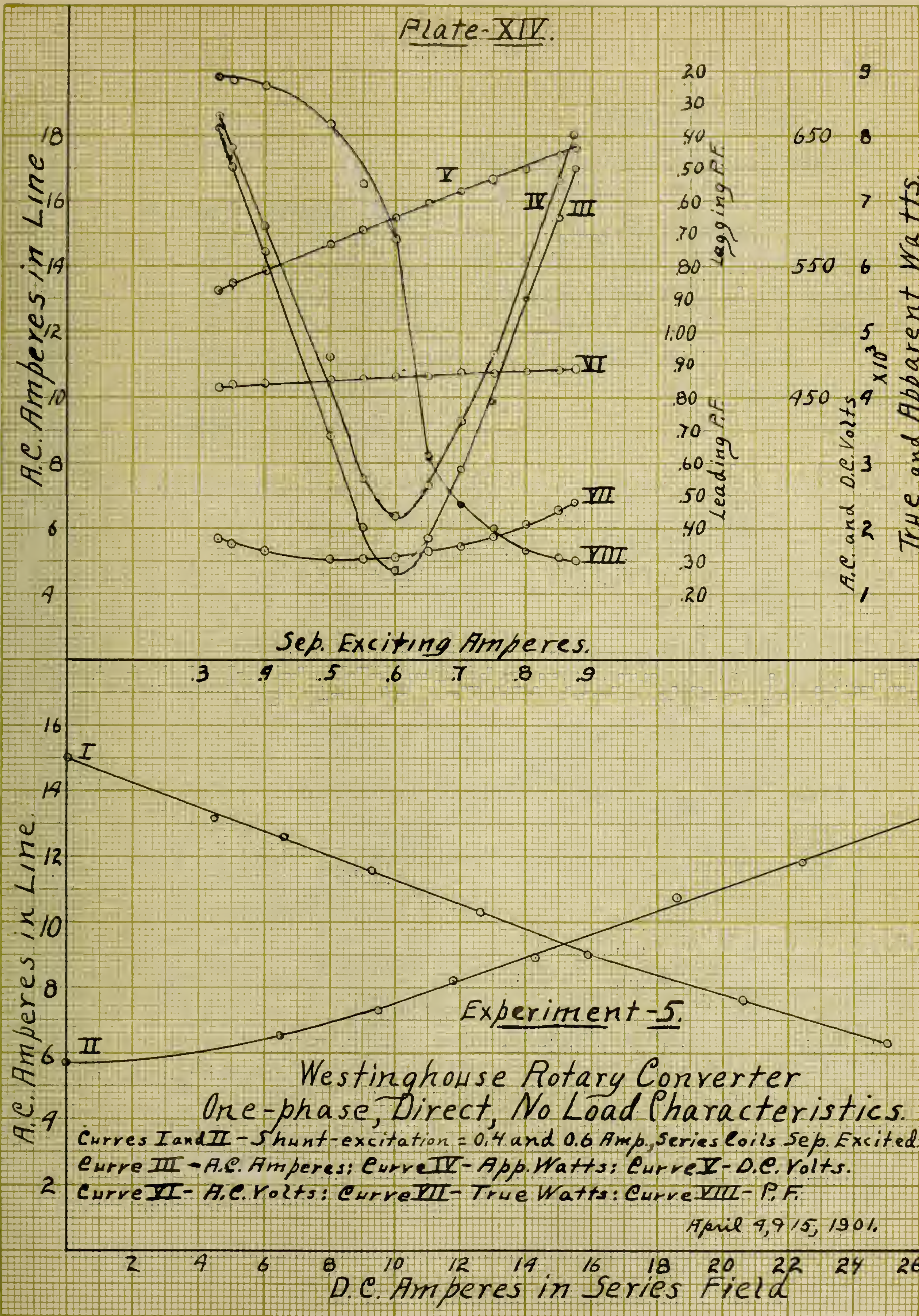


Plate-XIV.
A.C. Amperes in Line
Lagging P.F.
Leading P.F.
A.C. and D.C. Volts
True and Apparent Watts.
x10³
650
550
450
I
II
III
IV
V
VI
VII
VIII
Sep. Exciting Amperes.
A.C. Amperes in Line.
Experiment-5.
Westinghouse Rotary Converter
One-phase, Direct, No Load Characteristics.
Curves I and II - Shunt-excitation = 0.4 and 0.6 Amp. Series Coils Sep. Excited.
Curve III - A.C. Amperes: Curve IV - App. Watts: Curve V - D.C. Volts.
Curve VI - A.C. Volts: Curve VII - True Watts: Curve VIII - P.F.
April 4, 9, 15, 1901.
D.C. Amperes in Series Field

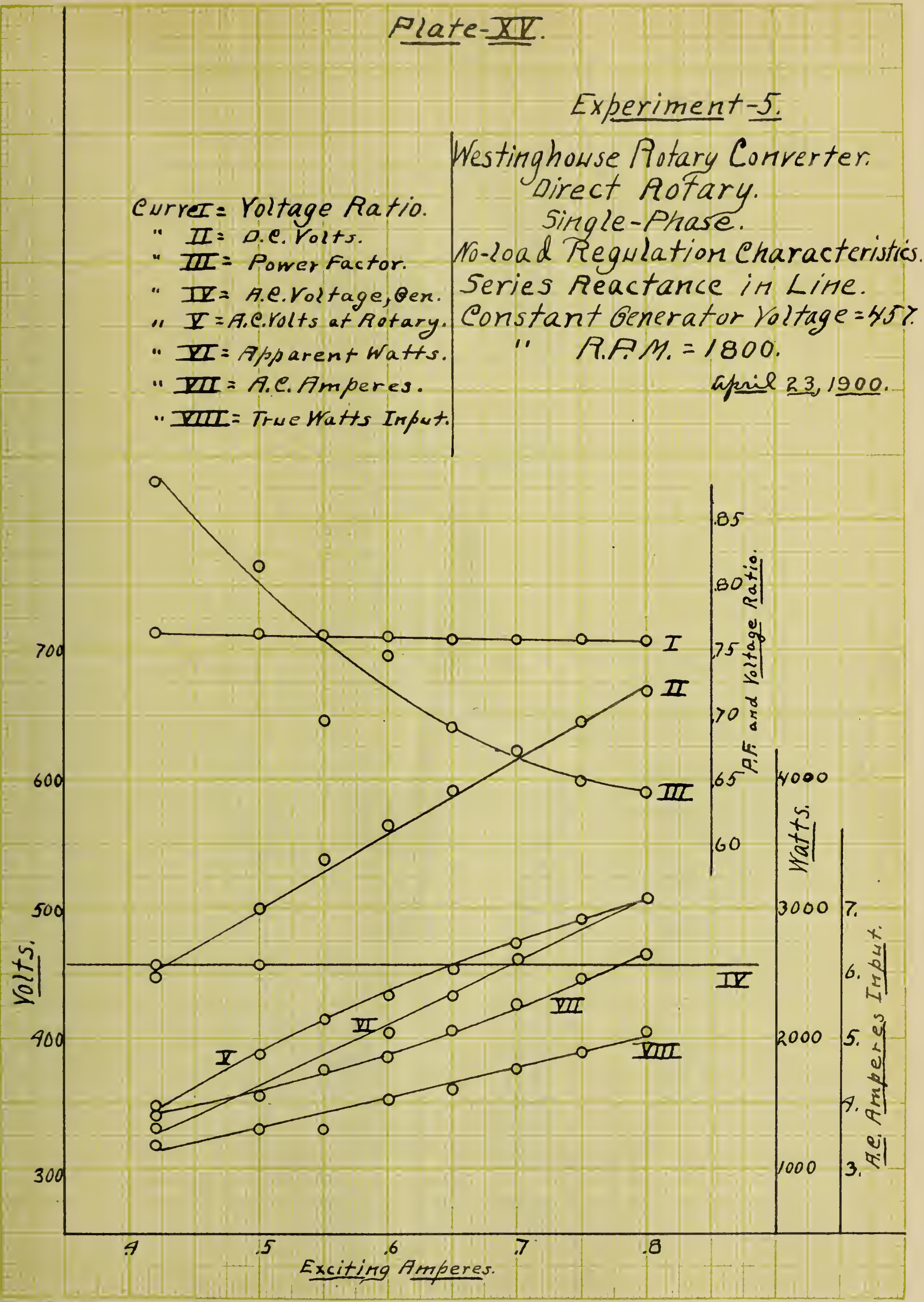


Plate-XV.
Experiment-5.
Westinghouse Rotary Converter.
Direct Rotary.
Single-Phase.
No-load Regulation Characteristics.
Series Reactance in Line.
Constant Generator Voltage = 457.
" R.P.M. = 1800.
April 23, 1900.
Curve I = Voltage Ratio.
" II = D.C. Volts.
" III = Power Factor.
" IV = A.C. Voltage, Gen.
" V = A.C. Volts at Rotary.
" VI = Apparent Watts.
" VII = A.C. Amperes.
" VIII = True Watts Input.
I
II
III
IV
V
VI
VII
VIII
Volts.
700
600
500
400
300
P.F. and Voltage Ratio.
.85
.80
.75
.70
.65
.60
Watts.
4000
3000
2000
1000
A.C. Amperes Input.
7.
6.
5.
4.
3.
.4
.5
.6
.7
.8
Exciting Amperes.

Plate XVI.

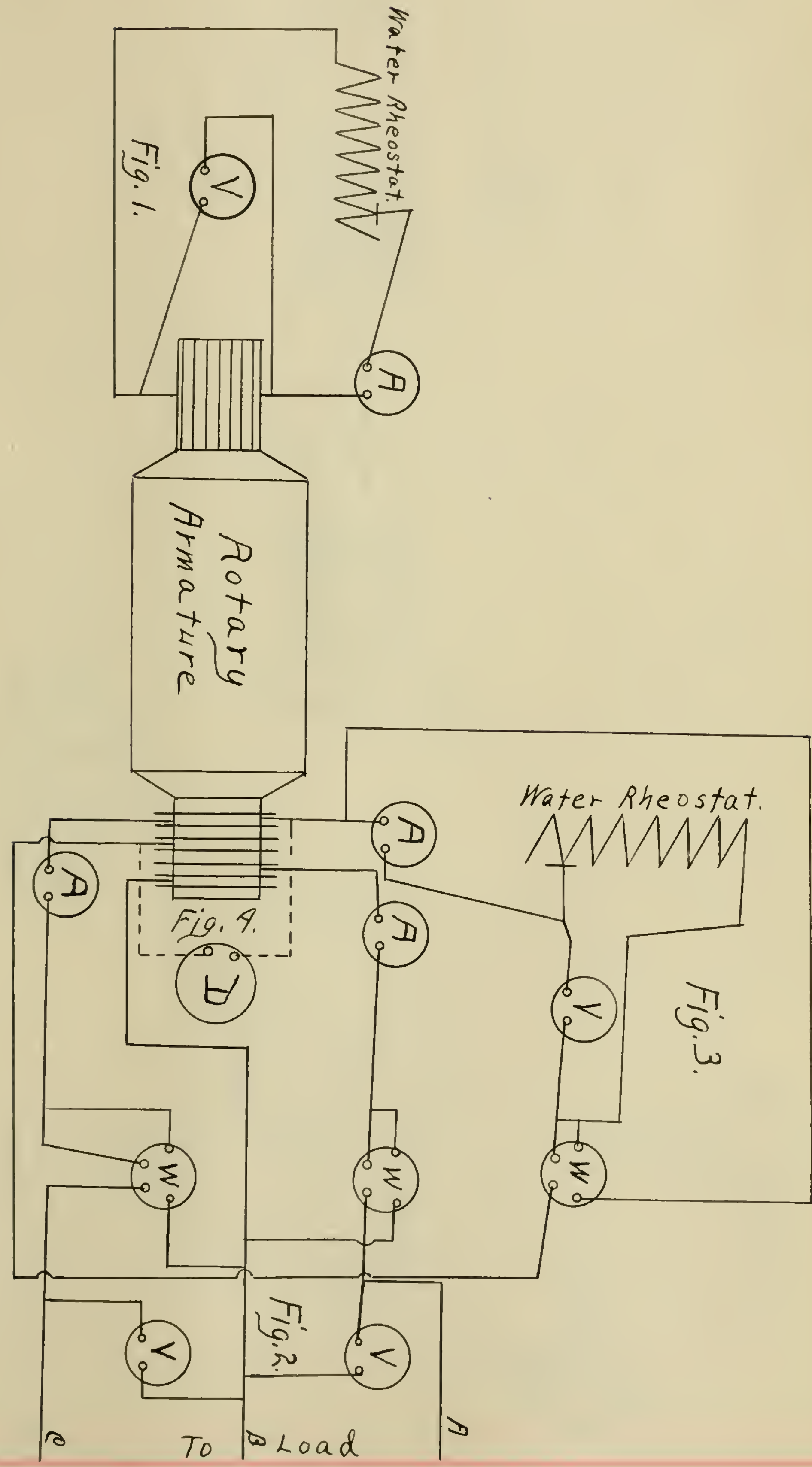

Water Rheostat.
Fig. 1.
V
A
Rotary Armature
Water Rheostat.
A
A
A
Fig. 4.
D
V
Fig. 3.
W
W
W
V
Fig. 2.
V
C
To
B Load
A

Plate-XVII.

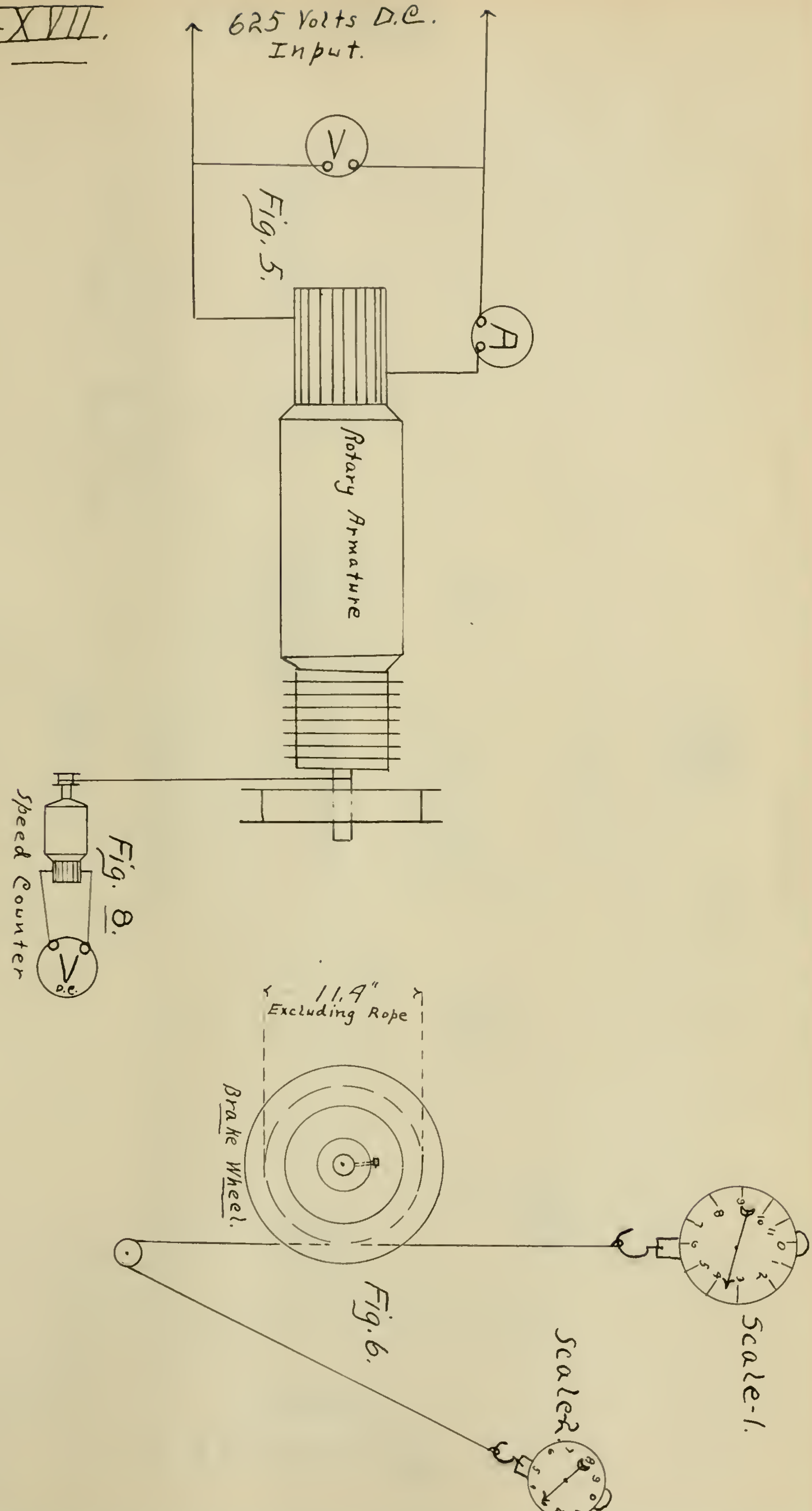

625 Volts D.C.
Input.
V
A
Fig. 5.
Rotary Armature
Fig. 8.
Speed Counter
V
D.C.
11.4"
Excluding Rope
Brake Wheel.
Fig. 6.
Scale-1.
Scale-2.

Plate XVIII.

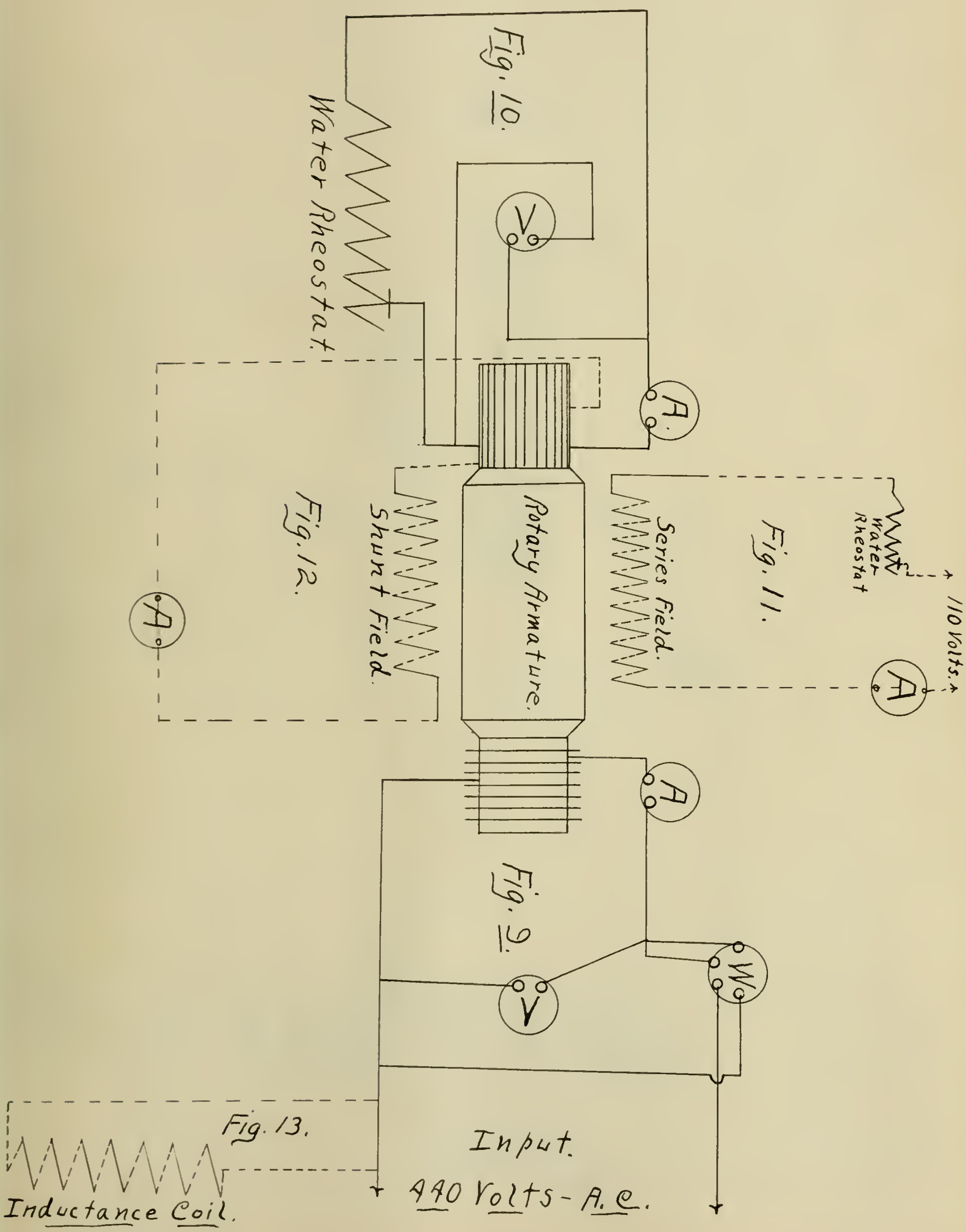


Fig. 10.
Water Rheostat.
V
A.
Fig. 12.
A
Shunt Field.
Rotary Armature.
Series Field.
Fig. 11.
Water Rheostat
110 Volts.
A
A
Fig. 9.
V
W
Fig. 13.
Inductance Coil.
Input.
440 Volts - A.C.

Plate XIX.

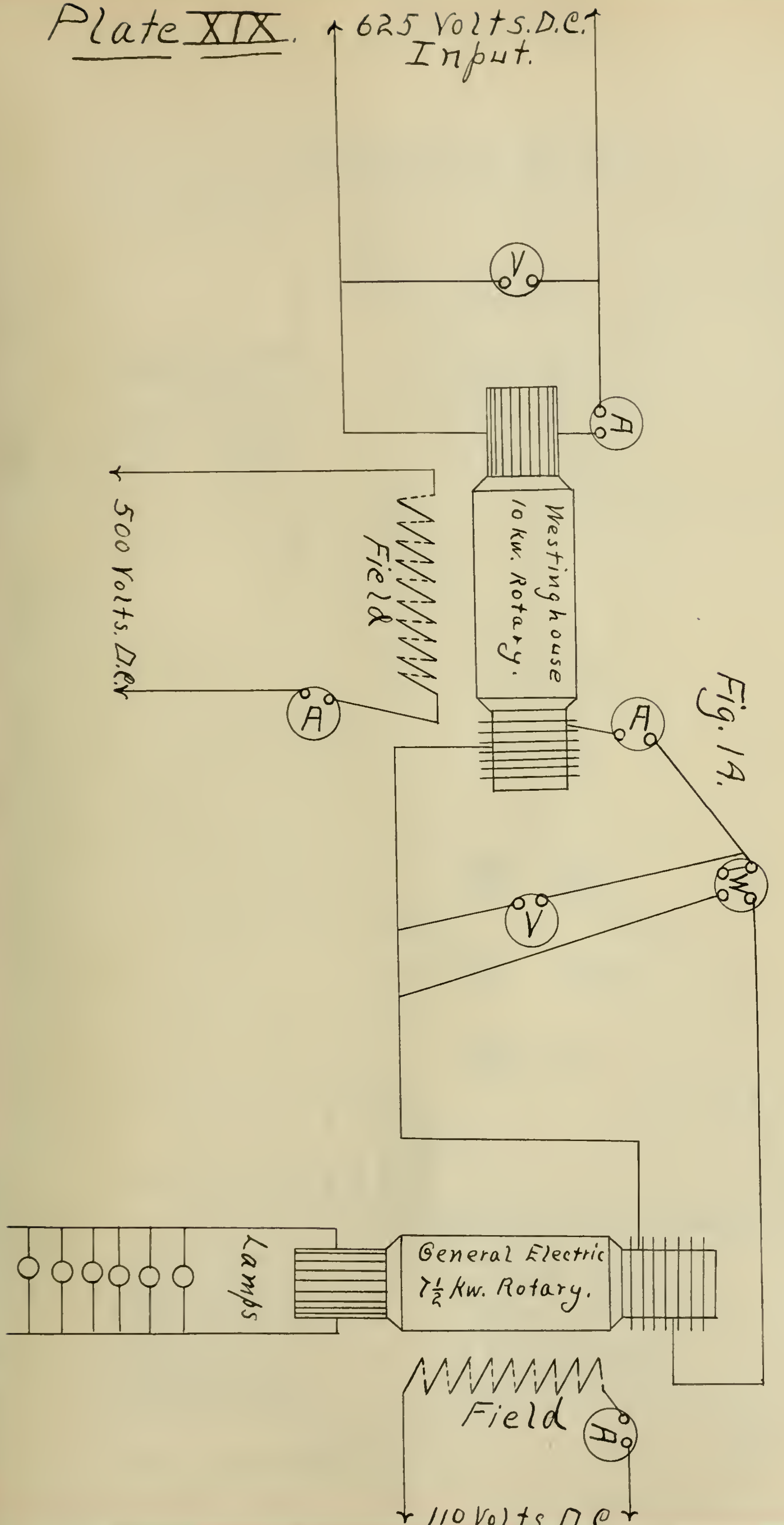


Fig. 1A.

Plate-XX.

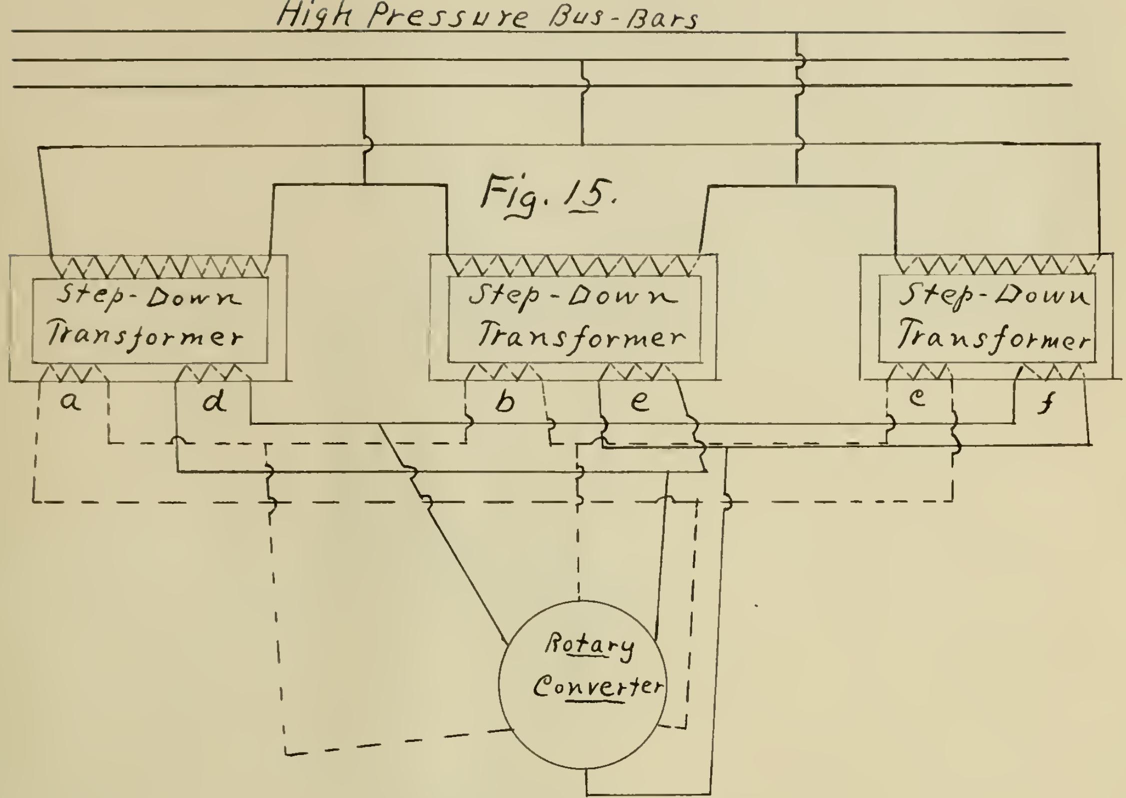


Fig. 15.

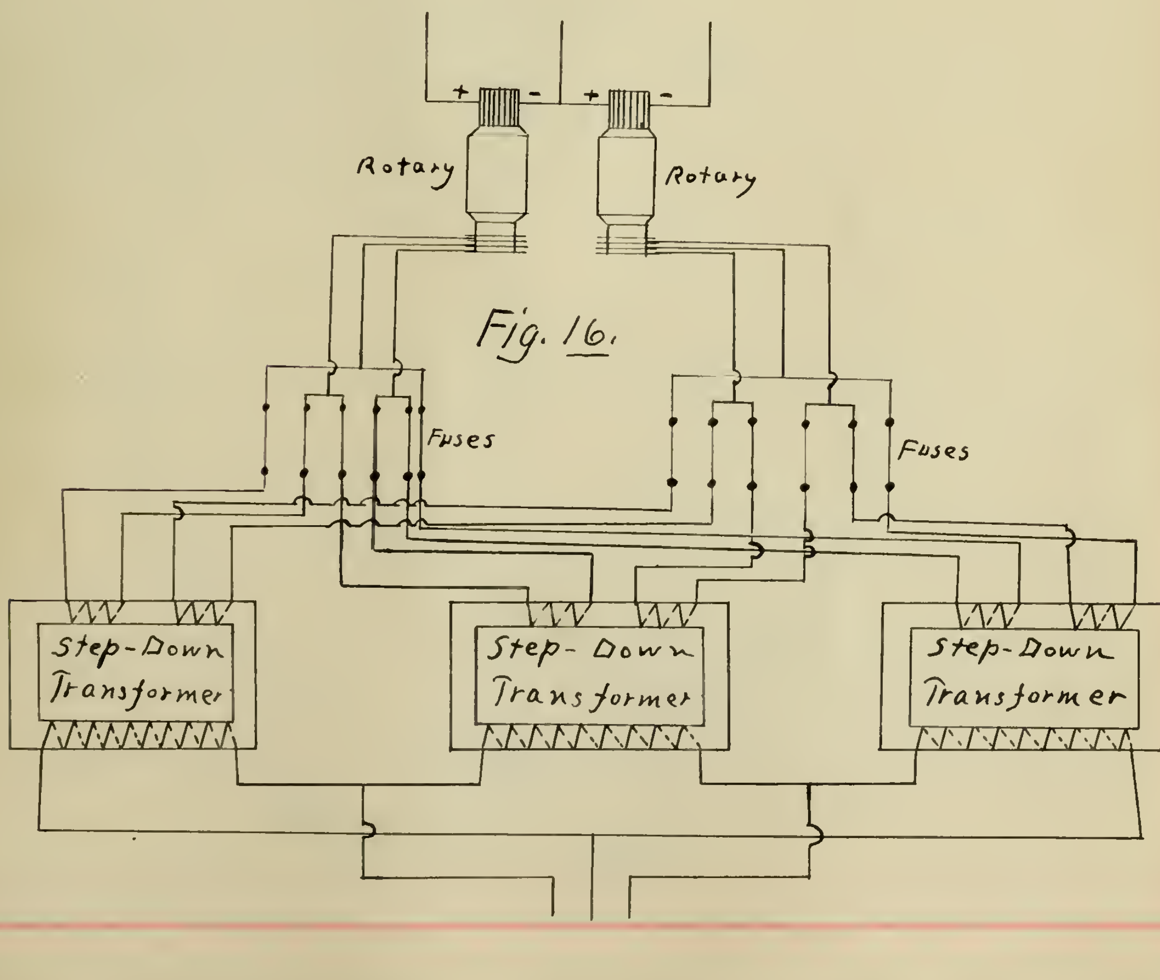
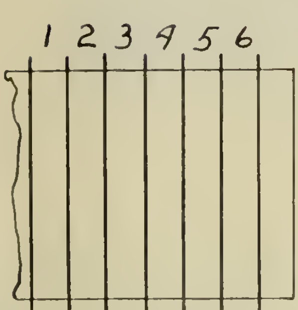
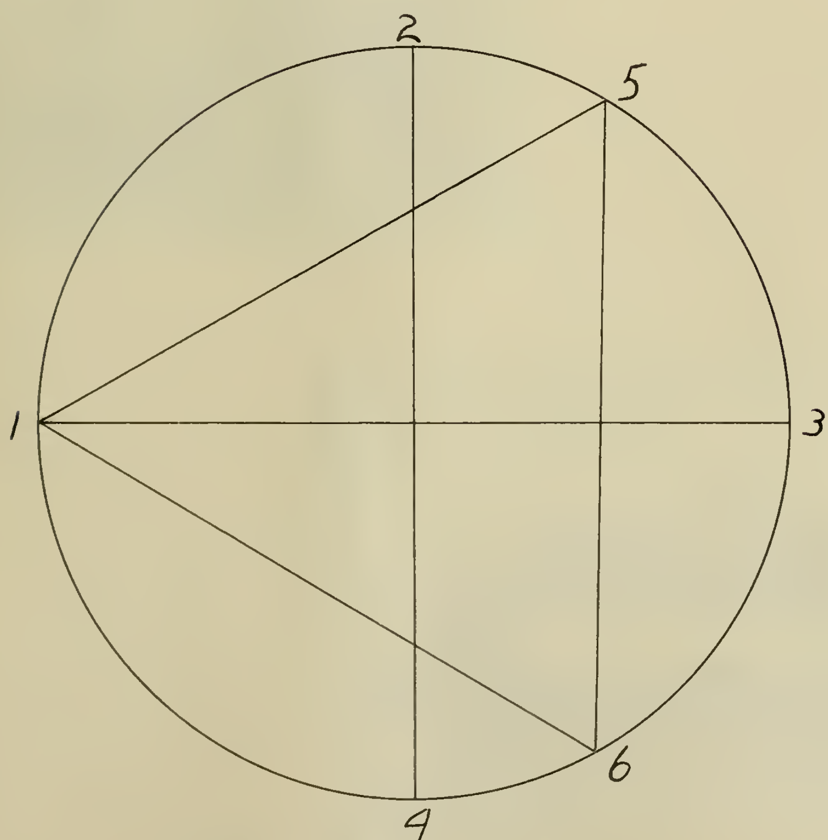


Fig. 16.

Plate-XXI.



Collector Rings



Armature Taps.

Plate-XXII.

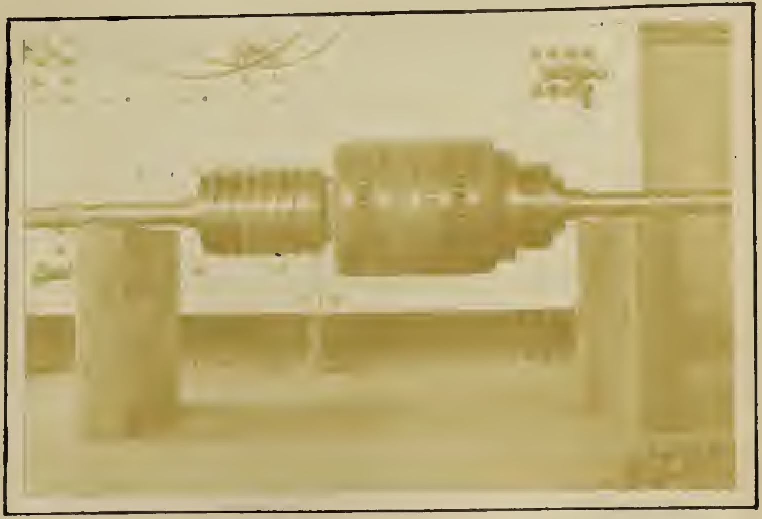
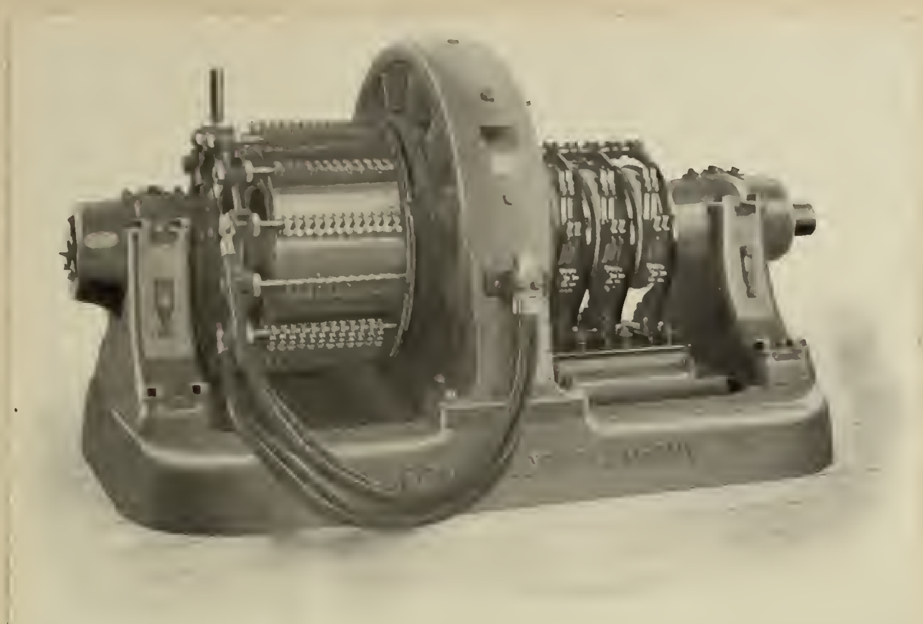
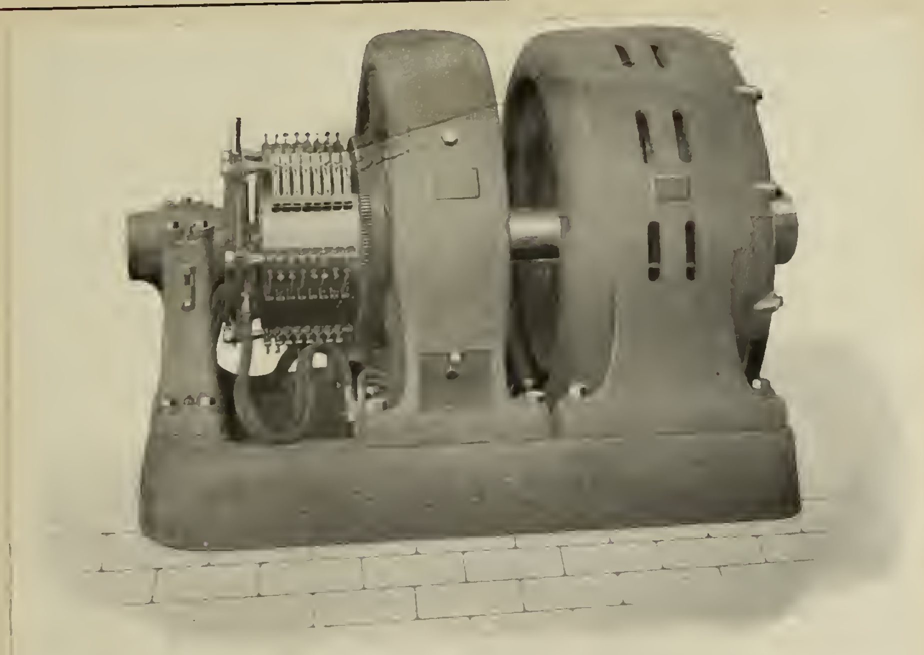


Plate-XXIII.



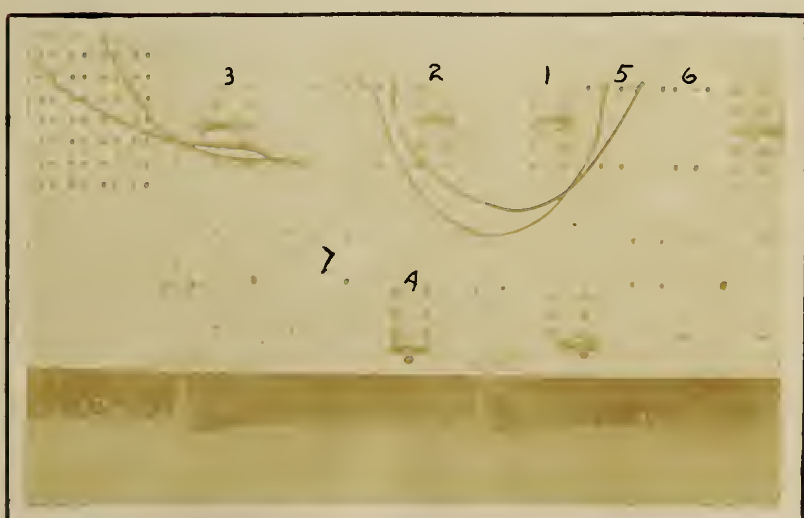
THREE-PHASE ROTARY CONVERTER.



MOTOR-GENERATOR SET.

Plate-XXIV.

1- Synchronizing Lamps
2-3- " Plugs.



1- D.C. Switch.
2-3- A.C. Switches.
4- Field Switch.
5-6- Two-phase-440 volts- Plant.
7- Field Terminals.